EFFECTS OF LAND MANAGEMENT AND HABITAT CHANGE ON WET MEADOW INVERTEBRATE DIVERSITY IN SOUTH-CENTRAL NEBRASKA

A Thesis
Presented to the
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In Partial Fulfillment
Of the Requirements for the Degree
Master of Science Biology
University of Nebraska at Kearney

by
Justin Richard Krahulik
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Thesis Acceptance

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Acceptance for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Science, University of Nebraska at Kearney.

May 2002

Supervisory Committee

Name	Department
	Platte River Trust
	Biology
	BIOLOGY
	Biology

Supervisory Committee Chair

5-3-02

Date

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Abstract

I assessed diversity and abundance of wet meadow invertebrate communities along the Platte River in south-central Nebraska through a series of experiments conducted between 1999 and 2001. Invertebrates are used in ecological monitoring because of their rapid rate of response to changes in their environment. These responses allow cêrtain invertebrate taxa to be used to monitor the management practices that are implemented in the habitat that they are found in. I hypothesized that invertebrate composition is increasingly different between grazed and idle riparian meadows as the distance increases from the middle of sloughs to higher elevation sites because of the tendency for grazing animals to over utilize higher ground. I rejected this hypothesis because there were no significant differences in overall diversity or abundance between grazed and idled wet meadows and distance from the slough. Contrary to the hypothesis grazed sites generally had a higher invertebrate diversity and evenness than idled sites. I also hypothesized that invertebrate feeding guild composition would differ in grazed and ungrazed riparian meadows between slough depressions and slough ridges. I found that certain guilds did decrease in abundance and evenness in grazed sites when compared to idled sites and that there were also differences in taxa found in slough depressions versus slough ridges.

In addition to their use as biological indicators for assessment of land management, certain invertebrate taxa can be used to assess the impact of induced habitat change brought about by human manipulation. I examined ground beetle assemblages in wet meadows and cottonwood forest ecotones along the Platte River in south-central Nebraska. I hypothesized that wet meadows would have a larger assemblage of ground beetle species compared to the forest and ecotone. I found that there was a larger assemblage of species in the wet meadow habitat but it was not statistically significant. I also found that three of the four most abundant species were significantly more abundant in wet meadow habitats than in cottonwood forest or ecotone habitats.

This study was important because it represents the first assessment of management practices and how they effect invertebrate diversity in wet meadows along the Platte River. Also it is a good starting point for future studies to determine what effects that cottonwood forestation has had on invertebrate fauna along the Platte River in south-central Nebraska.

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TABLE OF CONTENTS

Chapter 1.

INTRODUCTION AND LITERATURE REVIEW

Biodiversity

One of the main themes of biology has always been the diversity of life and biologists use the term "biodiversity" to describe this theme. Wilson (1992) described biodiversity as the "whole variety and range of variation of living things". Hawksworth and Ritchie (1993), Humphries et al. (1995), and Oliver and Beattie (1996) suggested that biodiversity could be separated into four levels. These levels were ecosystem diversity, taxonomic diversity, species diversity, and genetic diversity. Beginning with ecosystem diversity each level increases in the amount of diversity it possesses, but the higher levels of diversity also depend directly on the lower levels for their existence. Because of their interconnection, all levels of biodiversity must be maintained to ensure that the "diversity of life" can be sustained into the future (Rowe 1992).

The importance of biodiversity is recognized more and more every day as I realize the number of species (conservatively three per hour) that are being lost through human disturbances (Wilson 1985). Ehrlich and Wilson (1991) stated that although the importance of all life forms for human welfare is being realized the extinction of wild species and ecosystems is being accelerated by human action. The study of biodiversity is still in its infancy and I are now only beginning to realize what impacts the loss of habitat and species may have on humans and the planet as a whole. The reason that biodiversity studies are lagging behind other areas of scientific investigation is the large amount of diversity of life that is found on Earth. To encompass all aspects of biodiversity a multidisciplinary approach must be used to analyze all four levels. However there are few individuals who have the knowledge and resources to measure all aspects when studying biodiversity, therefore only one aspect is usually studied.

Arthropods

Arthropods are the most diverse group of organisms on the earth, which makes them valuable for studies of biodiversity. Arthropods comprise nearly 80% of all described species, are a critical component in the majority of terrestrial ecosystems, and have great importance to humans (Wilson 1986). However, the general public's perception of arthropods is one of aversion, dislike, or fear particularly towards insects and spiders (Kellert 1993) and the majority of human society is unaware of the extent to which I depend on or benefit from the array of other forms of life (Lovejoy 1994). Consequently, the greatest efforts in the study of biodiversity are often directed towards those groups, such as birds, mammals, and fish, which have the highest profile in the public's perception (Blake and Foster 1998). In the past, these studies generally do not include data on the arthropods and their importance in ecosystem functioning.

However, more recently, attempts to measure, describe, and account for arthropod diversity and its importance in an ecological setting are being made. For example, arthropods have been used in numerous studies as a subset of the animal community as biological indicators in areas such as monitoring environmental or habitat quality, biodiversity preservation, habitat comparisons, management decisions, and habitat characterization (Teraquchi et al. 1981, Niemela 1997, Poulin and Lefebvre 1997, Siemann et al. 1997, Blake and Foster 1998, Maiolini et al. 1998, Greenwood et al. 1999 Kotze and Samways 1999, Kotze and Samways 1999). Arthropods are used as biological indicator species because of their rapid response to environmental changes (Castella et al. 1994 Maiolini et al. 1998). In addition, arthropods have been used because they are relatively easy and cost effective to sample and because they are numerous and diverse (Blumbery and Crossley Jr. 1987, Biological Survey of Canada 1994, Mommertz et al. 1996, Oliver and Beatttie 1996).

Arthropod Diversity at the Family Level

Species diversity in arthropod assemblages makes them potentially good candidates for biodiversity studies, but their diversity at the species level and the difficulties inherent in differentiating them also may inhibit their use. For esample, several authors stated that the incorporation of invertebrates in extensive surveys of terrestrial ecosystems is rarely considered cost-effective because sorting vast arrays of unidentified invertebrates can be a difficult task (Oliver and Beattie 1996, Kotze and Samways 1999). Thus, although the task of quantifying global biodiversity patterns is urgent, the magnitude of that task has forced ecologists to consider indirect methods for estimating species level biodiversity (Roy et al. 1996).

Ideally, sampling arthropods should be done as quickly and inexpensively as possible with habitat disturbance being kept to a minimum (Oliver and Beattie 1996, Mommertz et al. 1995). To make arthropods a cost-effective taxon for bio-indicative purposes, different techniques have been attempted. One low cost option is to obtain diversity estimates using higher-taxon richness as a surrogate or substitute for diversity values (Williams et al. 1997). Balmford et al. (1996) determined that one of the most promising potential surrogates is measuring diversity at higher levels such as genera or family and that genera or family richness can be used to predict species richness. Gatson et al. (1995) expressed that the numbers or richness of units at higher taxonomic levels (e.g. family) can equally be seen as surrogates for species richness. Of particular interest is the assessment of higher taxon diversity at the family-level as a replacement for species-level diversity assessment because using family-level diversity to replace species-level diversity has the potential to yield quick and more cost effective results (Balmford et al. 1996, Gatson et al. 1995, Hoback et al. 1999, Williams et al. 1997).

Despite the promise, current literature reviews have only found two studies that have used family level diversity as a surrogate for species diversity. Hoback et al. (1999) used trap color and placement to determine the insect family level diversity for an inland salt marsh and Roy et al. (1996) used family level diversity to describe eastern pacific marine molluscs.

Ground Beetles

One insect family that has proven to be a good biological indicator in Europe is the ground beetles (Coleoptera: Carabidae). Ground beetles occur in a wide range of habitats including tropical forests, deserts, arctic tundra, and prairies. Because the majority of ground beetles are polyphagous predators, most prefer open habitats that provide them with the space they need to freely move about on the ground (Theile

1977). There are more than 40,000 different species estimated to exist worldwide with over 2,000 occurring in North America. Ground beetles comprise about 5% of the total described insect species of the world and about 3% of the total described species on earth. In North America the approximately 2,000 species make them the third largest beetle family (Thiele 1977). There are also over 270 species of ground beetles known to occur in Nebraska, which represents about 13.5% of the North American species (Lovei et al. 1996). The diversity of ground beetles makes them an excellent candidate for biodiversity studies (Magura et al. 2000).

Ground beetles are the largest family of the beetle suborder Adephaga. Although they vary in body size and structure, ground beetles generally have an elongate body that is most often black or brownish in color. The majority of ground beetle species are nocturnal, but brightly colored species are generally diurnal. Ground beetles breed in the spring or fall of the year and thus are divided into two groups based on their breeding season. Ground beetles have three predaceous larval stages prior to pupating in the ground. Ground beetles consume approximately their own mass in food each day as both larvae and adults (Kromp 1999). Larval feeding is positively correlated with the overall size and fecundity of adult ground beetles (Kromp 1999).

The factors that have been identified to affect ground beetle habitat selection are temperature, humidity, food, and presence of competitors (Lovei and Sunderland 1996). Luff et al. (1989) found that soil moisture, pH, and vegetation structure are the three variables that best explain differences between assemblages of ground beetles.

Taxonomically and ecologically, ground beetles are better studied than many groups because they are predatory and are potentially important in biological control of pest species (Faragalla and Adam 1985, French et al. 1998, Crist and Ahern 1999, Kromp 1999). Kromp (1999) conducted an extensive review of ground beetle literature in agricultural ecosystems. While he concluded that most evidence for ground beetle predation of insect pests relied on laboratory feedings where no choice was given to the ground beetles, there is evidence from field studies that indicates that ground beetles are effective predators on insect pests. Several potential pest groups are preyed on by ground beetles including aphids, fly eggs and larva, beetle larva, caterpillars, and snails (Kromp 1999). There is also the potential for some ground beetles to act as biological weed control agents by feeding on seeds (Kromp 1999).

Ground Beetle Ecology

Multiple species of the same genus of ground beetles often co-occur in the same habitats, in addition, multiple genera, which are similar in their use of resources occur in the same habitat. When resources are limited, competition should be intense for those resources. Darwin (1885) stated the unlikelihood of this occurring when he wrote:

> Animals come into competition for food or resources…As the species of the same genus usually have, though by no means invariably, much similarity in habits and constitution, and always in structure, the

> struggle will generally be more severe between them, if they come into competition with each other than between the species of distinct genera.

There have been several definitions of competition used to demonstrate how species interact with each other. One common definition of competition described by Bakker (1961) is:

> The manifestation of the struggle for existence in which two or more organisms of the same or of different species exert a disadvantageous influence upon each other because their more or less active demands exceed the immediate supply of their common resources.

This definition of competition has two underlying outcomes, co-existence and competitive exclusion. For multiple species to co-exist each species must act more severely on itself than on the other species with which it competes (Varely et al. 1973). Conversely, competitive exclusion, also known as Gause's principle, occurs when the successful species has a more adverse effect on the other species than upon itself (Varely et al. 1973). Even though carabids have been well characterized in Europe and to a lesser extent in North America there is uncertainty with respect to mechanisms used by ground beetles to co-exist in the same habitats.

Ground beetle competition has been observed in the field. Thiele (1977) found that it was possible for two species of the same genus to co-exist in various habitats such as grasslands or forest, whereas in another, immediately adjacent habitat, one of the species was present in large numbers but the other was rare or completely absent. This may indicate that competition is occurring in one habitat but not in the other. In addition, studies indicate that intraspecific and interspecific predation occurs among ground beetles and their larvae which will cannibalize members of their own brood as well as prey upon larva of other ground beetle species (Thiele 1977).

Ground beetle niche, which is the relationship of an organism to the environment it occupies, is that of a primarily predaceous arthropod that hunts on the ground. This niche is unusual because it is almost uncontested by other insects throughout the world (Thiele 1977). Thus, competition should be severe among ground beetles. The concept of niche can be used to explain why closely related species of carabids can co-exist. Tilman (1994) explains this phenomenon by stating:

> Within a habitat an organism is more likely to interact with neighboring organisms than with more distant ones…because each individual organism exists at a discrete point in space…the discreteness of individual organisms means that all organisms live in a spatially structured, subdivided habitat…subdivision may allow the stable coexistence of two species that are incapable of coexisting in any single site. This stable coexistence does not depend on any underlying physical heterogeneity or barriers in the habitat…it requires individuals to compete only in their neighborhoods…and for species to have appropriate trade-offs.

Tilmen (1994) also states that individuals of a single species cannot occupy all the sites in a habitat, which allows inferior competitors to invade and survive in the open portions of that habitat.

The Platte River

The Platte River is the major river system in Nebraska. It begins in the Rocky Mountains, with its two major tributaries, the North and South Platte Rivers. At the confluence of the North and South Platte Rivers, near the city of North Platte

Nebraska, the river is known as the Platte River and continues east until it empties into the Missouri River. Historically, the Platte River was a wide, shallow, braided river with sandbar formations surrounded by areas of wet meadows, tall-grass prairie, and sparse woody vegetation (Currier et al. 1985, Johnson 1994). Following westward expansion by settlers, the Platte River has been diverted and dammed to accommodate the area's agricultural economy. Impounding of the Platte's water altered the annual flood cycle of the river (Johnson 1994) and the flow of ice sheets in the spring that would dredge the sandbars and wet meadows removing woody vegetation.

This alteration changed the Platte River ecosystem transforming the river ad its banks from sparsely wooded pre-settlement conditions with wide, un-vegetated channels to the present condition with extensive cottonwood (*Populas deltoidies)* forests lining much narrower channels (Johnson 1994). As the river channels began to narrow because of reduced flows it subsequently led to a decline in the water table and a drying of the area's wet meadows. The alteration of the wet meadows from forestation and declining water tables has presumably altered the fauna dependant upon the wet meadow ecosystem. However, the lack of historical records of fauna prior to forestation makes it difficult to assess the impact of habitat change on fauna along the Platte River.

The Big Bend region of the Platte River is located in south-central Nebraska approximately from Lexington to Chapman. This stretch of the Platte River is where the majority of remaining open channel and wet meadow habitats are located and also comprises a large part of the central flyway which is a route used by migratory birds as they travel during their annual migrations. Migratory birds such as cranes and resident grassland bird species use the wet meadows to forage for arthropods, which are an important part of their diet (Currier 1985). The wet meadows are managed generally for migratory bird purposes. Hay production and cattle grazing occur as the chief management practices on the wet meadows. Blake and Foster (1998) suggest that if these habitats are to be managed for the benefit of their avian fauna, it is important to consider the effects of management practices on the invertebrates on which the birds depend. It is unclear what effect these management practices exert on the arthropod community. However, some studies have shown that grazing increases diversity by reducing competition from dominant species allowing rare species of arthropods to persist (Rambo and Faeth 1999).

Study Sites

Invertebrate Data

Sampling was conducted at the Whooping Crane Critical Habitat Maintenance Trust (Platte River Trust) and Audubon's Rowe Sanctuary during late April, early June, mid July, and late August through early September in 1999 and 2000. Eight sites were used to sample invertebrates using pitfall traps (Figure 1). Two management practices (grazed and idled) each containing four study sites (management and area of each site is located in Table 1) were compared. Each site was at least 20.2 hectares. The grazed conditions comprised wet meadows that were grazed throughout the growing season, with the number of cattle and duration of grazing being determined by the tenant who leased the land. The idle conditions included wet meadows that were left rested from either grazing or haying management practices.

Ground Beetle Data

Sampling occurred from April through October, 2001 at the Platte River Trust and Audubon's Rowe Sanctuary. Three sites were used to examine ground beetle assemblages in wet meadow and cottonwood forest habitat. Pit fall traps were opened approximately every other week and monitored for one-week periods.

Climate

The climate in south-central Nebraska is best characterized as continental with hot dry summers and long cold winters. The average precipitation in this region is 45.7 cm in the west (semiarid) and 66 cm in the east (semihumid) of the state with means between 40 and 50 cm for areas encompassing the study sites (Anonymous 1997).

Objectives

Effects of Grazing on Diversity

The objectives for this project were: 1) Determine if invertebrate composition differs between grazed and idle riparian meadows as the elevation increases from the middle of sloughs or depressions; 2) Determine if invertebrate feeding guild composition differs between idled and grazed riparian meadows between slough depressions and slough ridges.

Ground Beetle Community Structure

The objectives for this project were: 1) Determine if ground beetle diversity and community structure vary based on habitat type (wet meadow, cottonwood forest, and the transition zone); 2) Extend the knowledge of ground beetle habitat requirements along the Platte River and measure the colonization of the cottonwood forest, a relatively recent habitat.

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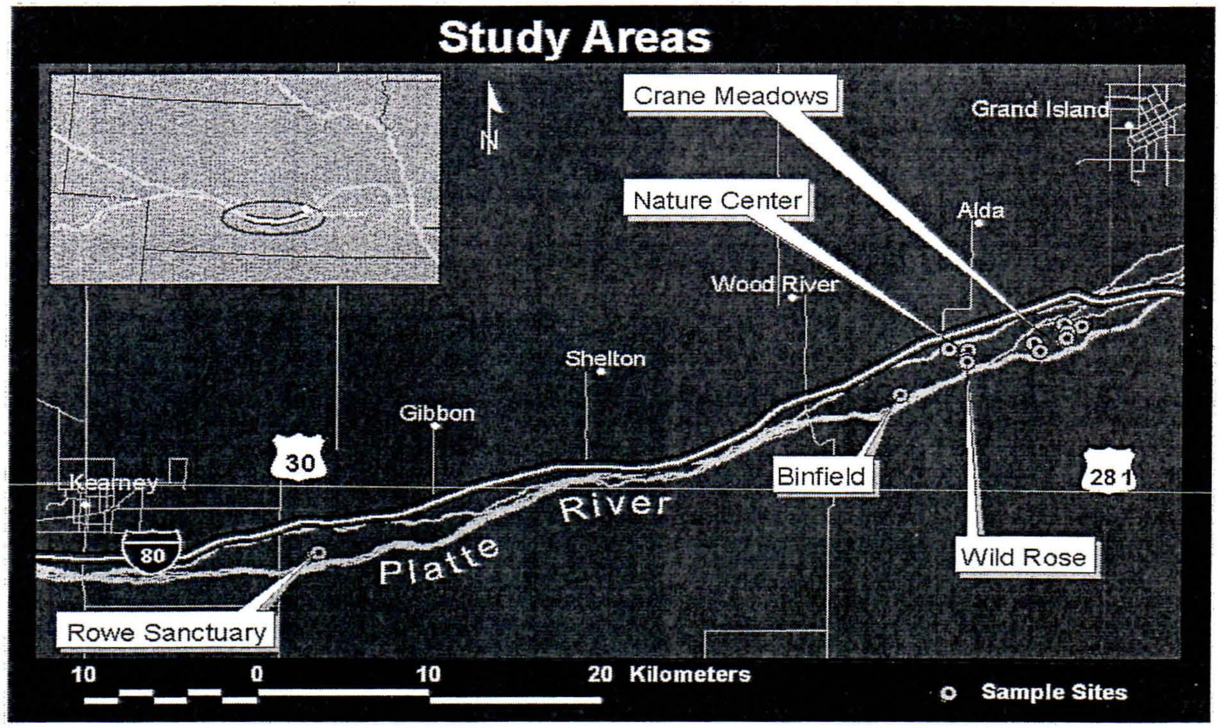
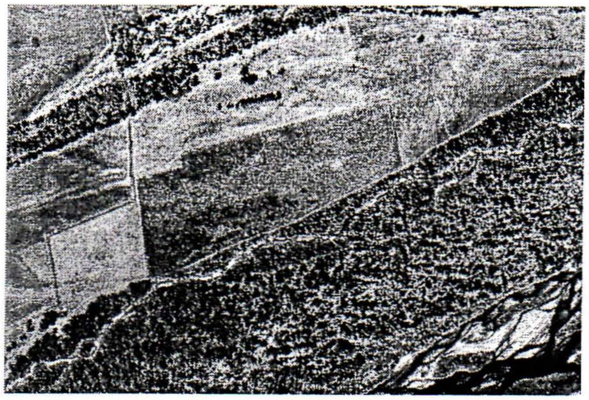
Table 1. Management Practice and Area of Study Sites

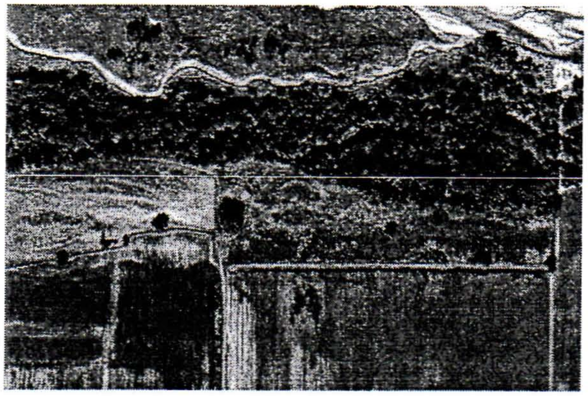
Site	**Management**	**Area in Hectares**
BINF	Grazed	48.6
MI02	Grazed	104.5
MI10	Grazed	91.5
MI12	Grazed	103.6
MI3E AND MI3W	Idled	109.3
NAC1 AND NAC2	Idled	93.1

Figure 1. Study Sites for Influence of Grazing on Wet Meadow Invertebrate Communities in South-Central Nebraska.

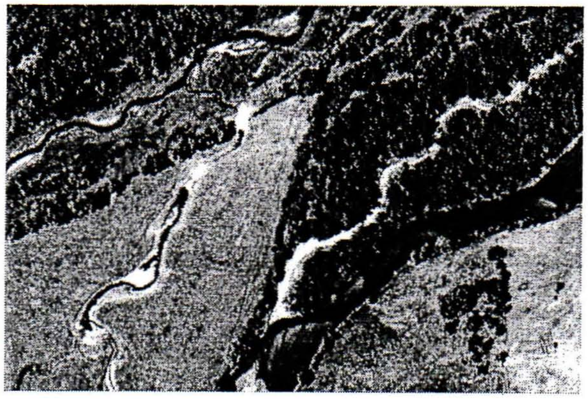




Study site 1



Study Site 2



Study site 3

Figure 2. Study Sites for Ground Beetle (Coleoptera: Carabidae) Assemblages in South-Central Nebraska in Wet Meadow/Cottonwood Forest Habitats.

Chapter 2:

Influence of Grazing on Wet Meadow Invertebrate Communities in South-Central Nebraska

Justin R. Krahulik[1], W. Wyatt Hoback[1], Craig A. Davis[2], and Jane E. Austin[3]

[1]Department of Biology, University of Nebraska at Kearney, Kearney NE 68849
[2]Department of Zoology, Oklahoma State University, Stillwater, OK 74078
[3]USGS- Biological Resources Division, Northern Prairie Wildlife Research Center, Jamestown, ND 58401

Abstract:

Arthropods comprise a critical component of managed ecosystems. Within these managed ecosystems, land-use practices may greatly affect the arthropod community. I assessed the impacts of different land-use practices on grassland arthropod communities along the Platte River in south-central Nebraska. I used pitfall traps to examine the effects of grazing in wet meadows on arthropod diversity and abundance along elevational gradients in 1999 and 2000. Pitfall traps consisted of arrays (N= 15 per site, 8 sites) of four 475 ml cups with 0.3 meters of drift fencing placed between them. Traps were opened for a 48 h period during the spring and summer of 1999 and 2000. Specimens were identified to family and family-level Shannon and Simpson diversity indices were calculated. I examined a total of 59,734 specimens belonging to 169 taxonomic groups (order or family). Low elevation grazed transects had the highest Shannon diversity (9.08) compared to all other transects. Simpson Index estimates of evenness were also highest for the low grazed transects (8.23). The low elevation idled transects had more invertebrate predators (2,054) than other treatments and mixed feeders were most numerous (4,852) on high elevation idled transects. Medium elevation grazed transects had the highest number of detritivores (3,031) while high elevation grazed transects had the highest number of herbivores (978). Based on these results, managed grazing does not appear to reduce invertebrate diversity, biomass, or abundance in wet meadows and thus can be used as an effective management practice to maintain these sensitive areas.

Introduction

The influences of grazing on grassland plant community structure have been documented, however there is continuing debate about the overall effects that grazing livestock has on these communities. Several studies present contradictory data that grazing can increase or decrease plant diversity depending on environmental factors and stocking rates (Weaver and Darland 1948, Milchunas et al 1988, Milchunas and Lauenroth 1993, Fleischner 1994, Biondini and Manske 1996, Weber et al. 1998, Rambo and Faith 1999). Weaver and Darland (1948) concluded that through overuse lowland prairie degenerates and loses productivity while Milchunas et al. (1988) concluded that the differences in response to grazing in semiarid and subhumid situations arise primarily from differences in the grazing tolerance of plants adapted to semi-aridity or of plants adapted to competition for light. Fleischner (1994) concluded that grazing had a multitude of effects in western North America including reducing density and biomass of plant and animal species, creating reduced biodiversity, facilitating the spread of exotic species, interrupting ecological succession, impeding nutrient cycling, changing habitat structure, and disturbing community organization. Contrarily, Weber et al. (1998) concluded that under moderate grazing pressure that there was little change in plant cover and resulting ecosystem function until a threshold was reached when rapid change in cover would occur.

Grazing likely also affects invertebrate communities of grassland ecosystems because plant diversity is directly correlated with invertebrate diversity. For example, Hendrix et al. (1988) suggested that the number and diversity of invertebrates have been explained in various ways but the underlying theme in all these explanations is that invertebrate diversity mimics plant diversity. Siemann et al. (1998) also found that increasing plant diversity significantly increased invertebrate diversity. In contrast, Rambo and Faith (1999) found that grazing increased plant diversity and plant richness, grazing caused decreases in insect abundance (Rambo and Faith 1999).

Modeling work by East and Pottinger (1983) suggests that invertebrates respond in three different ways to grazing: A type I response is a population decline as stocking rates increase, a type II response is an increase to a peak population under medium stocking rates with a decline at higher stocking rates, and a type III response is a population increase as stocking rates increase. Although East and Pottinger (1983) descriptions of possible invertebrate responses are useful as a starting point, few experiments have been conducted and no general model of grazing intensity has established thresholds for when the various types of response will be observed.

Invertebrates are important in decomposition and nutrient recycling in the majority of terrestrial ecosystems (Douce and Crossley 1982). Ecosystem management seeks to maintain the structure and function of an entire ecosystem rather than individually managing organisms of interest (Lapin and Barnes 1995). The establishment of ecosystem management practices as alternatives to more traditional methods of grazing management, have helped to influence grazing and habitat managers to seek understanding of the impact of grazing at the ecosystem level (i.e. determine grazing impacts on invertebrates and other organisms). In part, ecosystem management has arisen because agricultural land use practices such as grazing are a major cause of declines in biodiversity (Soule 1991). Ecosystem management incorporates the importance of all organisms and how they benefit other organisms in their environment (Blake and Foster 1998). To maintain the natural species diversity of the typical flora and fauna, management objectives must be complemented by grazing practices based on ecological knowledge of their effects (Dennis et al. 1997).

In this study I evaluated the impact that grazing has on invertebrate communities in wet meadows along the Platte River in south-central Nebraska. Wet meadows have a unique topography consisting of narrow depressions called swales that traverse the interior of wet meadows. Vegetation gradients are formed from the elevational change in the swale. The bottom of the swale depression has wetland plant species and the top or swale ridge has subirrigated plant species (Currier et al1985). I hypothesized that swale depressions in grazed wet meadows would have a higher diversity and abundance of invertebrates when compared to the swale ridges. I also hypothesized grazing would impact swale ridges to a greater extent than swale depressions because cattle tend to graze higher areas more intensely.

Materials and Methods:

Study Site

Arthropod abundance and distribution were studied on eight wet meadow sites along the Big Bend Region of the Platte River in south-central Nebraska. Sample sites ranged in size between 23.5 hectares to 109.4 hectares. Four of the wet meadows were grazed by cattle and four were pristine wet meadow habitat.

Wet meadows are characterized as wet subirrigated prairie with wetlands traversing the interior in small shallow depressions called swales. Wet subirrigated sites are characterized by having the water table near the surface in years with average precipitation to a depth of 0.61 meters below the surface in dry years. Subirrigated sites have a unique composition of vegetation, which is characterized by big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), indiangrass (*Sorghastrum nutans*), prairie cordgrass (*Spartina pectinata*), blue joint reedgrass (*Calamagrostis canadensis*), and northern reed grass (*Calamagrostis neglecta*) (Nebraska Cooperative Extension 2002). Other plants, which may be found in a subirrigated site, include little bluestem (*Schizachyrium scoparius*), Canada wildrye (*Elymus canadensis*), slender wheatgrass (*Agropyron trachycaulum*), Kentucky bluegrass (*Poa pratensis*), green muhly (*Muhlenbergia racemosa*), and various sedges (*Carex* spp.) (Nebraska Cooperative Extension 2002). Wetland sites are characterized by having a seasonably high water table that ranges from above the soil surface in wet to average years to 0.30 meters below the soil surface in dry years. Principal plants on a wetland site include prairie cordgrass, blue joint and northern reedgrasses, reed canarygrass (*Phalaris arundinacea*), sedges, and rushes (*Juncus* spp.), and less than 5% forbs (Nebraska Cooperative Extension).

Rainfall

Summer precipitation influences the distance to water table and the amount of water in sloughs. Compared to 30 year averages, 1999 was a wet year with + 6.4 cm of precipitation in June, - 1.5 cm in July, and + 9.3 cm in August. In contrast, 2000 was a dry year with – 7.8 cm in June, - 0.64 cm in July, and -1.3 cm in August (Nebraska State Climate Office 2001).

Grazing Management

Grazing occurred on four sites in 1999 and 2000. The Platte River Trust determined grazing duration and stocking rates. Sites were only grazed during the growing season from May to September and were grazed on a rotation schedule. Stocking rates were approximately 1aum per acre.

Trapping Method

Transects were placed along three elevational gradients. Low transects (N= 8) were placed in the swales and high transects (N= 8) were placed along ridges above the swales and medium transects (N= 8) were placed between high and low transects. Pitfall trap arrays were used to collect arthropods from the wet meadows. Each transect had 5 trap arrays that were approximately 9 meters apart. Trap arrays consisted of four 475 ml plastic cups with a diameter of 8.9 cm. Traps were covered with a plastic rain shield that was suspended approximately 5 cm above the opening of the cup using long nails. This helped protect the specimens from desiccation and scavenging from vertebrates. Between each cup was a piece of .3-meter drift fencing, which was constructed using plastic garden edging. Each trap was filled with 1:1 ratio of ethylene glycol and ethyl alcohol for specimen preservation. Upon collection specimens were placed in collection jars in the field and transported to the laboratory for latter identification.

Sampling was conducted during four sampling periods (April, late May- early June, July, and late August- early September) over a two-year period during 1999 and 2000. Traps were opened for a 48 hour period during the sampling dates.

Organisms collected were identified to family or order. All insects were identified to the family level while other trapped invertebrates including spiders, isopods, and centipedes were identified to order or class. Once specimens were identified, they were dried for 24 hours in a drying oven at 70° C and dry mass was measured in grams for all organisms collected.

Guild Data

Trapped organisms were placed into guilds based on food preference of adults and larva. There were four guild types used: predator, herbivore, detritivore, and mixed feeder (which were designated when food preferences differed between members of the same family). Guild-level response was tested to determine if there were differences between grazed and idle sites in the community structure. Guilds were also used to examine differences between high, medium, and low transects in the grazed and idled conditions.

Statistical Tests

Mean Shannon-Wiener indices were calculated to determine family richness in each management practice and Simpson indices were calculated to determine taxa evenness (Magurran 1988). Effects of grazing on these indices were compared using analysis of variance (ANOVA). Multivariate analysis of variance (MANOVA) with a factorial arrangement was used to examine differences in the responses of numbers and biomass of invertebrates, and guild taxa by treatment, transect height, and period. Because of large variations in rainfall and subsequent differences in wet meadow conditions, years were analyzed separately. Following a significant overall MANOVA, univariate ANOVA was used to determine differences in treatments ($P = 0.05$) and where differences were detected Tukey tests were used to separate means.

Results

Effects of Grazing on Arthropod Diversity and Biomass

There were 25,988 total invertebrate specimens collected in 1999, with 12,452 collected from grazed sites compared to 13,536 collected from idled sites. In 2000, there were 36,253 specimens collected, 17,319 from grazed sites and 18,944 from idled sites. Across treatments diversity measures were similar among grazed and idled sites and among transect heights resulting in no significant differences (ANOVA, $P > 0.05$). Grazed sites had slightly higher mean taxa richness, but lower evenness in 1999 for high and medium transects for all periods combined (Table 1). Numbers of taxa were not consistently different between treatments ranging between 69 taxa for high grazed sites in 1999 and 2000 and 53 taxa for high idled sites in 2000 and for low grazed sites in 2000 (Table 1). When mean diversity and evenness across season by transect height and treatment was calculated, grazed sites had both slightly higher average diversity (all comparisons except 1999 medium transect; Figure 1) and slightly higher evenness (all comparisons except 1999 high transect and 2000 low transect; Figure 2).

During 1999, biomass was similar among transects, and by treatment (Table 1). There were no significant differences between biomass of invertebrates, period, transect height, or between treatments for either year (ANOVA, $P > 0.05$). Mean invertebrate biomass was generally higher for grazed sites except for medium transects in 1999 and high transects in 2000 (Figure 3).

Effects of Grazing on Invertebrate Guilds

Predators were generally more abundant in idle sites compared to grazed sites, however the difference was significant [F (1, 1099) = 13.41, $p < 0.001$] only in 1999. Transect height had significant effects in both years with the majority of predators collected from low sites in both 1999 [F (2, 1099) = 4.05, $p < 0.02$] and 2000 [F (2, 1176) = 21.338, $p < 0.001$]. Between low grazed and idled treatments in 1999 there were significantly more predators in idled sites compared to grazed sites [F (2, 1099) = 3.96, $p < 0.005$]. There were also significantly more predators in idled low sites than there were in idled high sites [F (2, 1099) = 3.96, $p < 0.005$].

Members of the herbivore guild were generally more abundant in idled than grazed conditions in 1999 and 2000, but the difference was significant only in 2000 [F (1, 716) = 9.533, $p < 0.04$]. Herbivores differed in abundance by transect height but the difference was not consistent between years. In 1999, there were significantly more herbivores collected in high transects than from medium or low transects [F (2, 721) = 3.71, $p < 0.04$] while in 2000, there were significantly more herbivores collected from high transects than from medium transects [F (2, 716) = 3.87, $p < 0.05$].

The mixed feeder guild was slightly more abundant in 1999 in grazed sites ($P > 0.05$), however in 2000 there were significantly more mixed feeders in idled sites than in grazed sites [F (1, 923) = 4.75, $p < 0.05$]. Transect height had significant effects in both years with the majority of mixed feeders collected from high sites in 1999 [F (2, 993) = 5.51, $p < 0.01$] and in 2000 [F (2, 923) = 6.37, $p < 0.01$]. Within grazed sites, there were significantly more mixed feeders in high sites than in low sites in 1999 [F (2, 993) = 2.30, $p < 0.05$] and in 2000 [F (2, 923) = 3.01, $p < 0.05$]. Within idled sites, significantly more mixed feeders were collected from high sites than from low sites in 2000 [F (2, 923) = 3.01, $p < 0.01$]. During the first period in 2000, there were significantly more mixed feeders in idle high sites compared to grazed high sites [F (6, 923) = 2.04, $p < 0.01$]. There were no significant differences among all other periods in 2000 or for any period in 1999.

The detritivore guild was more abundant at idled sites in 1999 than grazed sites [F (1, 855) = 8.92, $p < 0.001$] but in 2000 there were slightly fewer collected from idled sites than grazed sites ($P>0.05$). For both years, there were significantly more detritivores collected from period 1 idle sites than from period 1 grazed sites [F (2, 855) = 2.77, $p < 0.001$]. No other significant differences were detected ($P > 0.05$).

Discussion

Grazing exerted no significant effects on overall invertebrate numbers, diversity, or richness although during both years, fewer invertebrates (8% less in 1999 and 9% less in 2000) were collected from grazed sites. Despite fewer invertebrates, the overall biomass was generally higher for grazed sites compared to idled sites suggesting that on average larger taxa were more abundant in grazed sites (Figure 3). These results may be explained because organisms were sorted to the family level. For example, if species within the family respond differently to grazing because larger species withstand grazing better than smaller species, grazing would favor larger organisms. Alternatively because pitfall trapping was conducted the results may be explained by taxa moving in response to grazing and thus being trapped more frequently than in idled sites (see discussion below). This possibility may be supported by the fact that despite higher numbers of specimens collected in idled sites, average species richness and diversity values were generally higher for grazed sites than for idled sites (Figures 1 and 2).

Surprisingly, invertebrate biomass was fairly consistent across the season except in 2000 when more invertebrate biomass was collected during periods three and four. This observation may reflect differences in summer rainfall between years (1999 was a normal year while 2000 was much drier). To further examine the impacts of grazing on invertebrates, the responses of invertebrate feeding guilds were examined.

Feeding Guilds

I found a number of significant differences among invertebrate guilds, however, the differences were not consistent between years. In general herbivore numbers were not affected by grazing except in 2000 when the medium and low transects of idled sites had significantly more herbivores than the same elevations in grazed conditions (Figure 4). Of the guild taxa, herbivores were the least collected averaging less than three specimens per transect. This observation is unusual because primary consumers form the prey base for other taxa. However, the observation may be explained by herbivore behavior. Although adult herbivores and hemimetabalous nymphs such as grasshoppers are mobile and move from plant to plant, many adult and larval herbivores develop while feeding on a single host plant. Thus, it is not surprising that few herbivorous beetle larvae (2 scarab larvae for all samples) were collected in pitfall traps during this study compared to taxa such as the motile predaceous ground beetle larvae (total of 57 during the study).

In addition, the observed herbivore data may be explained by the relatively low number of taxa assigned to the herbivore guild (Table 2). For this study, the feeding preference of the collected life stage (i.e. adult, larva) was used to designate feeding guild. Thus, several families of flies were assigned to the mixed feeding category because as adults (which were collected) they feed on nectar, pollen, or detritus while as larvae (which were not collected) they are herbivorous.

The mixed feeder guild includes families in which species within a family feed on different types of food. There were significantly more mixed feeders in idle sites in both low and high transects in 2000 while there were slightly more mixed feeders in all grazed transects in 1999 (Figure 5). These differences may be explained by the dry conditions of 2000. Arguably the most important mixed feeder guild taxa included in this study was the ants. The ants are ground nesting and susceptible to flooding effects and were thus potentially limited in their use of swales in 1999. Differences between high sites in grazed and idled conditions are likely explained by the effects of cattle trampling on ant nests as has been found by previous studies showing changes in dominant ant species in response to grazing (Nash, et al. 2000; Usnick, 2000).

Predators were generally more abundant in low transects than in either medium or high transects for both years and except for medium transects, there were more invertebrate predators collected from idle sites than from grazed sites (Figure 6). This pattern may be explained by the general sensitivity of predatory species to disturbance (e.g. Halaj et al. 2000). Grazing disturbance reduced numbers of predatory taxa such as ground beetles (Dennis et al. 1997) and spiders (Dennis et al. 2001) because of soil compaction from trampling and because of changes in vegetative structure.

There were significantly more detritivores in idle high and low sites in 1999 but not 2000 (Figure 7). In 2000, there were generally more detritivores in grazed sites but the differences were not significant. Our detritivore category included species that feed on decaying vegetation and associated fungi as well as those species such as scarab beetles which feed on dung. The findings for 1999 generally contradict our expectation that more dung-feeding detritivores would be collected from grazed sites. My findings of similar or fewer numbers of detritivores may suggest that these insects are not as likely to leave the dung pats and encounter the pitfall arrays, or that detritivore numbers are limited during active grazing periods by cattle disturbance. In addition, my observations may be explained because grazed sites have less litter than idled sites and thus at the family level, detritvore response to grazing may be masked.

Sampling Bias

Pitfall traps are likely ineffective for sampling all families within the wet meadow community. Some larger and stronger insects probably escaped the traps and flying insects such as many bees, wasps, and dragonflies will not be caught. In the future, small-scale absolute sampling (where all above ground invertebrates are captured and counted in an area) should be used to calibrate trap efficiency and to determine if the pattern of rare families is an artifact of sampling technique or is biologically meaningful.

A final sampling issue that must be tested in the future is the assumption that all members of an insect family will show a similar response to pitfall traps. At present, few studies have examined multiple species primarily because the majority of tests have targeted a particular insect pest. Tests involving trap response by multiple species within a family have produced mixed results (See Hoback et al.1999).

I know of no studies which have examined the relative proportion of invertebrate guilds collected by pitfall traps, but such a study could shed light on sampling biases due to differences in the behaviors of various guilds as has been observed within some insect families (Hoback et al. 1999). In addition, Dennis et al.

(2001) found suction sampling of spiders to reveal significant differences among grazed and control sites for spiders while pitfall trapping of the same sites revealed no significant differences.

Management Implications

Wet meadow restoration faces multiple challenges in recreating and maintaining plant diversity and associated animals of pristine wet meadow habitat. These challenges involve the selection of the best ecosystem management to maintain the restored sites while controlling invasive species such as brome grass and eastern red cedar. Management options include burning, mowing, haying, idling, and grazing. In this paper I compared the effects of managed grazing versus a hands-off approach on invertebrate diversity and abundance which influence the use of these habitats by grassland bird species. From the results of this study, I found that invertebrate abundance and diversity was relatively insensitive at the family level even when environmental conditions were very different between years. Thus, it appears that managed grazing is a valuable tool in maintaining wet meadow habitat in south-central Nebraska.

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Table 1. Total Shannon-Wiener Diversity Index, Simpson Diversity Index, number of taxa, number of specimens, and dry mass of all organisms collected by year and transect height.

Year	**Treatment and Year**	**Transect Height**	**Shannon Index**	**Simpson Index**	**# Taxa**	**# Specimens**	**Dry mass (grams)**
1999	Grazed	High	8.53	7.65	69	4,024	74.87
	Idle	High	7.50	7.92	66	5,059	63.78
	Grazed	Medium	7.99	7.56	55	3,702	52.28
	Idle	Medium	7.84	8.04	66	5,228	61.05
	Grazed	Low	9.08	8.23	65	2,455	38.66
	Idle	Low	7.52	6.71	61	3,246	35.06
2000	Grazed	High	6.50	3.89	69	4,214	40.36
	Idle	High	4.52	2.35	53	7,344	49.29
	Grazed	Medium	6.03	4.45	55	6,917	72.28
	Idle	Medium	5.74	4.13	56	5,045	38.46
	Grazed	Low	6.90	6.73	53	6,146	77.98
	Idle	Low	6.25	5.90	55	6,354	57.78

Table 2. Summary of taxa collected by treatment and the guild to which they were assigned.

Class	Order	Family	Condition		Guild [a]
			Idled	**Grazed**	
Arachnida	Acarina		60	102	Mix
Arachnida	Araneida		4,733	3,531	Pred
Arachnida	Chelonethidae		1		Pred
Arachnida	Phalangida	Phalangida	679	965	Pred
Hexopoda	Coleoptera	Anthicidae	1	4	Mix
Chilopoda		Chilopoda	6	5	Pred
Diplopod		Diplopoda	661	67	Det
Isopoda			5,487	6,245	Det
Hexopoda	Coleoptera	Bruchidae		1	Herb
Hexopoda	Coleoptera	Byrrhidae	1		Herb
Hexopoda	Coleoptera	Cantharidae	49	37	Mix
Hexopoda	Coleoptera	Carabidae	1,675	1,621	Pred
Hexopoda	Coleoptera	Cerambycidae	1	3	Herb
Hexopoda	Coleoptera	Chrysomelidae	57	113	Herb
Hexopoda	Coleoptera	Cicindelidae	6	24	Pred
Hexopoda	Coleoptera	Clambidae	3		Det
Hexopoda	Coleoptera	Cleridae	1		Pred
Hexopoda	Coleoptera	Coccinellidae	7	23	Pred
Hexopoda	Coleoptera	Colydiidae		1	Mix
Hexopoda	Coleoptera	Corylophidae	1		Mix
Hexopoda	Coleoptera	Cryptophagidae		1	Mix
Hexopoda	Coleoptera	Cucujidae	1	2	Pred
Hexopoda	Coleoptera	Curculionidae	95	136	Herb
Hexopoda	Coleoptera	Dermestidae	1	1	Mix
Hexopoda	Coleoptera	Dytiscidae	19	30	Pred
Hexopoda	Coleoptera	Elateridae	35	85	Herb
Hexopoda	Coleoptera	Endomychidae	1		Det
Hexopoda	Coleoptera	Eucnemidae	1	2	Det
Hexopoda	Coleoptera	Halictidae	3	7	Herb
Hexopoda	Coleoptera	Haliplidae		1	Pred
Hexopoda	Coleoptera	Heteroceridae		2	Pred
Hexopoda	Coleoptera	Histeridae	81	183	Det
Hexopoda	Coleoptera	Hydrophilidae	12	19	Mix
Hexopoda	Coleoptera	Lampyridae	430	363	Pred
Hexopoda	Coleoptera	Langurridae		1	Herb

Hexopoda	Coleoptera	Lycidae	4	7	Mix
Hexopoda	Coleoptera	Melandryidae	4		Mix
Hexopoda	Coleoptera	Meloidae	3	10	Herb
Hexopoda	Coleoptera	Melyridae	2		Mix
Hexopoda	Coleoptera	Mordellidae	7	7	Mix
Hexopoda	Coleoptera	Mutillidae		3	Mix
Hexopoda	Coleoptera	Nitidulidae	2,434	598	Det
Hexopoda	Coleoptera	Passalidae	1	1	Det
Hexopoda	Coleoptera	Pedilidae	1	1	Det
Hexopoda	Coleoptera	Phalacridae	1	1	Herb
Hexopoda	Coleoptera	Phengodidae	1		Pred
Hexopoda	Coleoptera	Pselaphidae	63	14	Det
Hexopoda	Coleoptera	Ptilodactylidae	4	10	Det
Hexopoda	Coleoptera	Scaphidiidae	8	9	Det
Hexopoda	Coleoptera	Scarabaeidae	456	892	Det
Hexopoda	Coleoptera	Scydmaenidae	1	1	Det
Hexopoda	Coleoptera	Silphidae	133	424	Det
Hexopoda	Coleoptera	Staphylinidae	443	521	Mix
Hexopoda	Coleoptera	Tenebrionidae	39	7	Det
Hexopoda	Collumbola	Entomobryidae	5	5	Det
Hexopoda	Diptera	Agromyzidae	1	0	Mix
Hexopoda	Diptera	Anthomyiidae	8	15	Mix
Hexopoda	Diptera	Anthomyzidae		2	Mix
Hexopoda	Diptera	Asilidae	5	3	Herb
Hexopoda	Diptera	Bibionidae	2	1	Det
Hexopoda	Diptera	Bombyliidae	1		Mix
Hexopoda	Diptera	Calliphoridae	1	5	Det
Hexopoda	Diptera	Ceratopogonidae	3	1	Mix
Hexopoda	Diptera	Chironomidae	1	1	Mix
Hexopoda	Diptera	Conopidae		1	Mix
Hexopoda	Diptera	Culicidae		4	Mix
Hexopoda	Diptera	Unknown larvae	10	6	Mix
Hexopoda	Diptera	Dolichopodidae	7	1	Pred
Hexopoda	Diptera	Drosophilidae		15	Det
Hexopoda	Diptera	Dryomyzidae		1	Mix
Hexopoda	Diptera	Ephydridae		3	Mix
Hexopoda	Diptera	Lauxaniidae	5	26	Mix
Hexopoda	Diptera	Muscidae	1	9	Mix
Hexopoda	Diptera	Mycetophilidae	3	1	Det
Hexopoda	Diptera	Pipunculidae	1		Mix
Hexopoda	Diptera	Pompilidae	3		Pred
Hexopoda	Diptera	Sarcophagidae	4	6	Det
Hexopoda	Diptera	Sciaridae	511	660	Det

Hexopoda	Diptera	Sciomyzidae	2		Pred
Hexopoda	Diptera	Sepsidae	1		Det
Hexopoda	Diptera	Simuliidae		2	Mix
Hexopoda	Diptera	Stratiomyidae	2	1	Mix
Hexopoda	Diptera	Syrphidae	6	13	Mix
Hexopoda	Diptera	Tachinidae	4	17	Mix
Hexopoda	Diptera	Therevidae		2	Pred
Hexopoda	Diptera	Tipulidae	12	14	Det
Hexopoda	Diptera	Trixoscelididae	25	56	Mix
Hexopoda	Ephymeroptera	Limnephilidae	5	6	Det
Hexopoda	Hemiptera	Alydidae	2	2	Herb
Hexopoda	Hemiptera	Corimelaenidae	4	9	Herb
Hexopoda	Hemiptera	Cydnidae	3	1	Herb
Hexopoda	Hemiptera	Hebrididae		10	Pred
Hexopoda	Hemiptera	Lygaeidae	1	15	Herb
Hexopoda	Hemiptera	Miridae	15	23	Herb
Hexopoda	Hemiptera	Nabidae	52	225	Pred
Hexopoda	Hemiptera	Pentatomidae	6	6	Herb
Hexopoda	Hemiptera	Phymatidae	8		Pred
Hexopoda	Hemiptera	Podopidae	3	3	Herb
Hexopoda	Hemiptera	Reduviidae	34	47	Pred
Hexopoda	Hemiptera	Rhopalidae	4	1	Herb
Hexopoda	Hemiptera	Saldidae	5	12	Pred
Hexopoda	Hemiptera	Scutelleridae	1		Herb
Hexopoda	Homoptera	Aphididae	2	26	Herb
Hexopoda	Homoptera	Cercopidae	166	192	Herb
Hexopoda	Homoptera	Cicadellidae	903	725	Herb
Hexopoda	Homoptera	Delphacidae	25	18	Herb
Hexopoda	Homoptera	Dictyopharidae	8	3	Herb
Hexopoda	Homoptera	Fulgoridae	1	13	Herb
Hexopoda	Homoptera	Gelastocoridae	4	3	Pred
Hexopoda	Homoptera	Issidae	67		Herb
Hexopoda	Homoptera	Psyllidae	1	1	Herb
Hexopoda	Hymenoptera	Apidae	3	7	Herb
Hexopoda	Hymenoptera	Braconidae	16	6	Mix
Hexopoda	Hymenoptera	Colletidae		3	Herb
Hexopoda	Hymenoptera	Diapriidae	1		Mix
Hexopoda	Hymenoptera	Formicidae	10,996	7,679	Mix
Hexopoda	Hymenoptera	Ichneumonidae	5	4	Mix
Hexopoda	Hymenoptera	Scelionidae	2	11	Mix
Hexopoda	Hymenoptera	Sphecidae	8	8	Pred
Hexopoda	Hymenoptera	Tiphiidae	3	2	Mix
Hexopoda	Hymenoptera	Vespidae		4	Pred

Hexopoda	Lepidoptera	Arctuiidae		1	Herb
Hexopoda	Lepidoptera	Danaidae		1	Herb
Hexopoda	Lepidoptera	Hespreiidae		2	Herb
Hexopoda	Lepidoptera	Lymnaeidae	1	2	Mix
Hexopoda	Lepidoptera	Noctuiidae	4	10	Herb
Hexopoda	Lepidoptera	Nymphalidae	3	1	Herb
Hexopoda	Lepidoptera	Papillionidae		1	Herb
Hexopoda	Lepidoptera	Pyralidae	66	41	Herb
Hexopoda	Lepidoptera	Satyriidae	1		Herb
Hexopoda	Lepidoptera	Sphingidae	1		Herb
Hexopoda	Orthoptera	Acrididae	62	294	Herb
Hexopoda	Orthoptera	Gryllacrididae	42	2	Herb
Hexopoda	Orthoptera	Gryllidae	1,384	2,227	Mix
Hexopoda	Orthoptera	Tetrigidae	51	61	Herb
Hexopoda	Orthoptera	Tettigoniidae	12	9	Herb
Hexopoda	Orthoptera	Tridactylidae	3	75	Mix
Hexopoda	Lepidoptera	Unknown larvae	38	77	Herb
Hexopoda	Lepidoptera	Notodontidae	1		Herb

[a] Pred: Predator, Herb: Herbivore, Det: Detritivore, Mix: Mixed Feeder

Figure Legends

Figure 1. Mean ± 1 S.E. Shannon Diversity values by transect height for grazed and idle sites in 1999 and 2000. There were no significant differences.

Figure 2. Mean ± 1 S.E. Simpson Diversity values by transect height for grazed and idle sites in 1999 and 2000. There were no significant differences.

Figure 3. Mean ± 1 S.E. biomass (g) by transect height for grazed and idle sites in 1999 and 2000.

Figure 4. Mean ± 1 S.E. number of herbivorous invertebrates by transect height for grazed and idle sites in 1999 and 2000.

Figure 5. Mean ± 1 S.E. number of mixed feeding invertebrates by transect by transect height for grazed and idle sites in 1999 and 2000.

Figure 6. Mean ± 1 S.E. number of predaceous invertebrates by transect by transect height for grazed and idle sites in 1999 and 2000.

Figure 7. Mean ± 1 S.E. number of detriverous invertebrates by transect by transect height for grazed and idle sites in 1999 and 2000.

Figure 1.

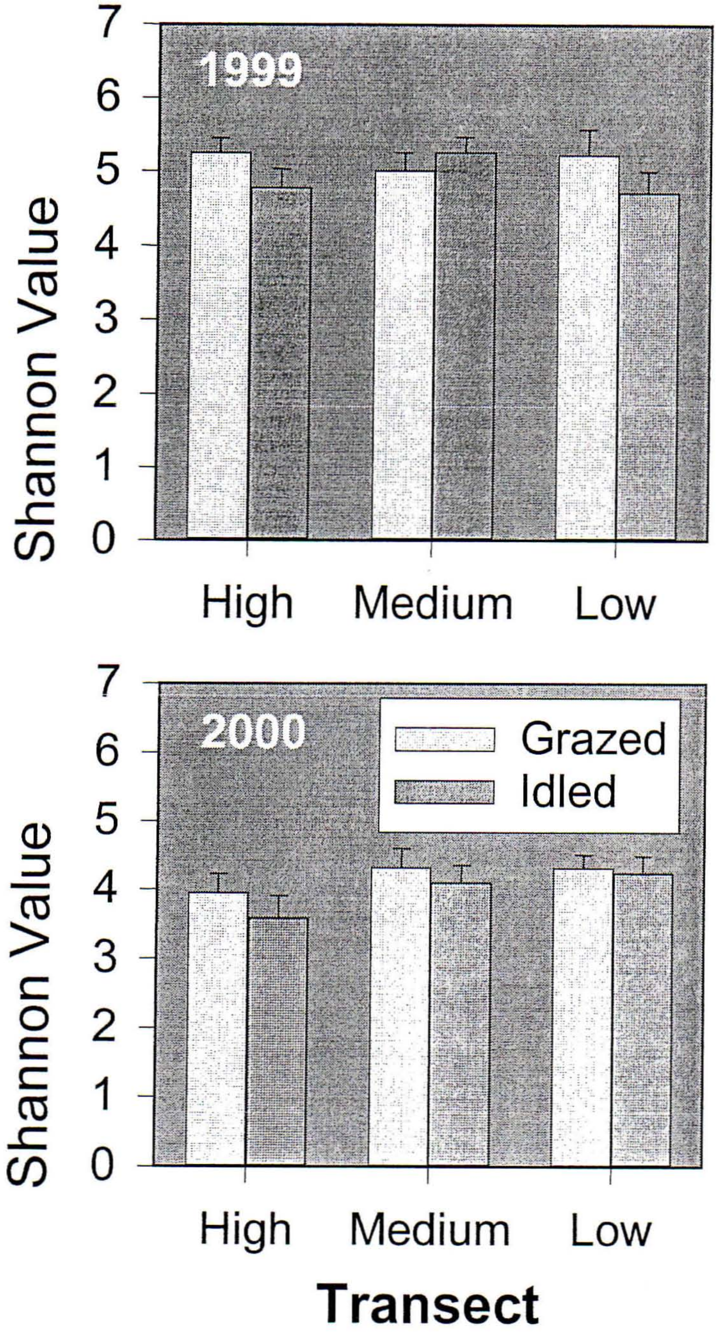

1999
Shannon Value
7
6
5
4
3
2
1
0
High
Medium
Low
2000
Grazed
Idled
Shannon Value
7
6
5
4
3
2
1
0
High
Medium
Low
Transect

Figure 2.

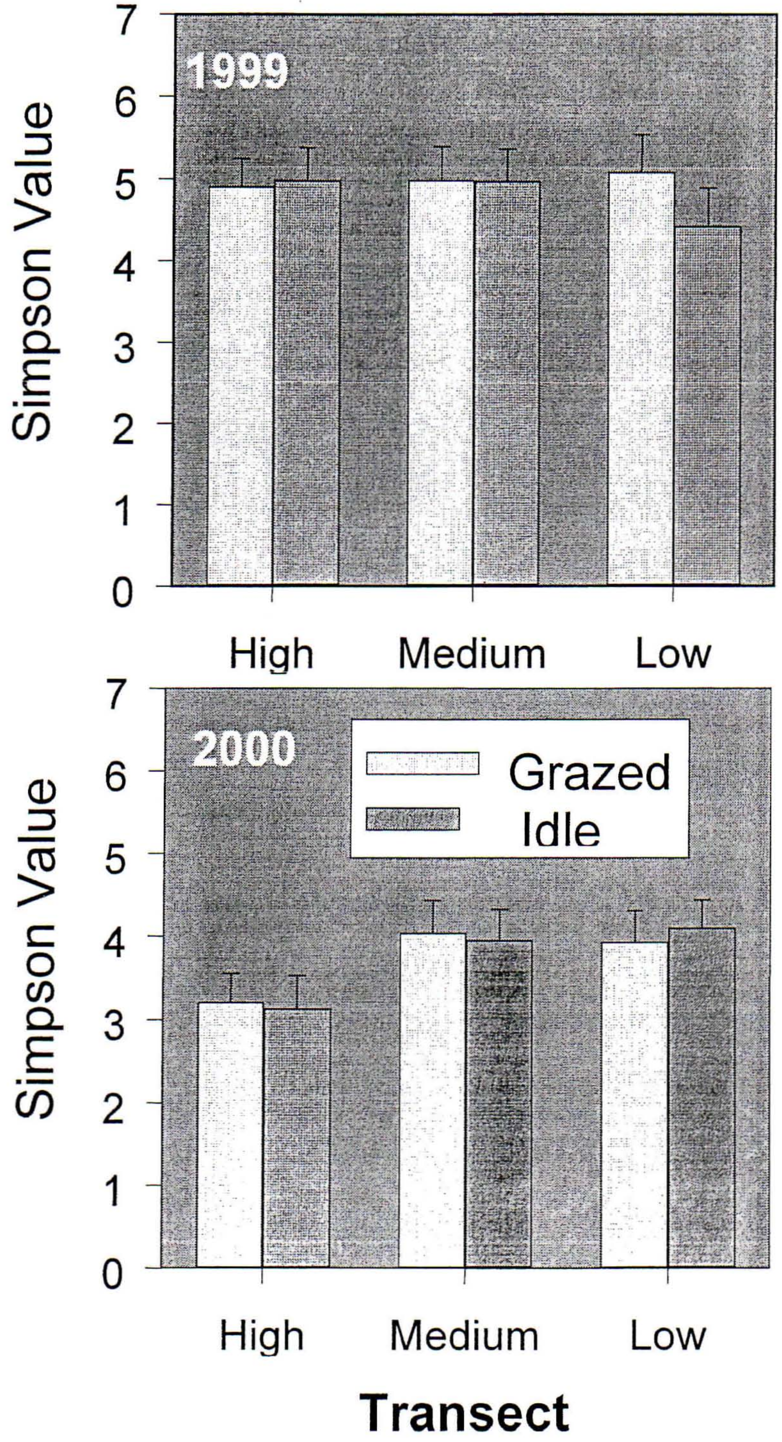

1999
Simpson Value
0
1
2
3
4
5
6
7
High
Medium
Low
2000
Grazed
Idle
Simpson Value
0
1
2
3
4
5
6
7
High
Medium
Low
Transect

Figure 3.

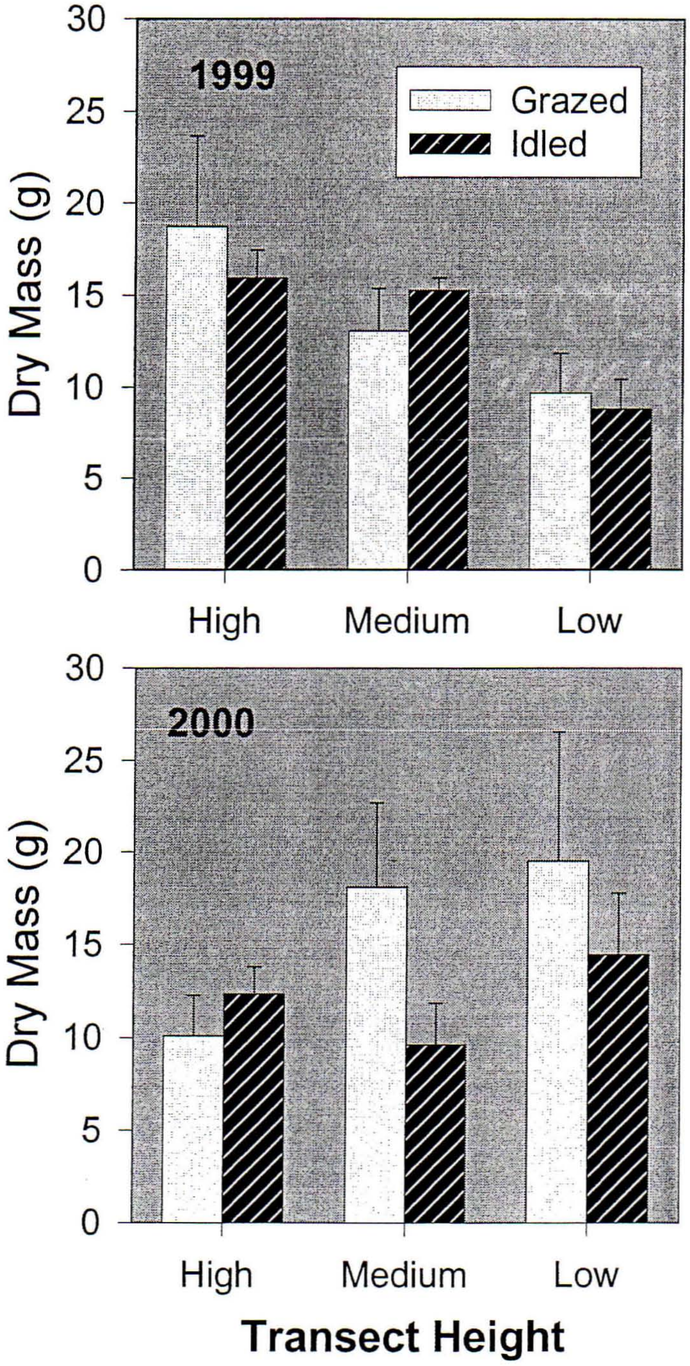

30
25
20
15
10
5
0
Dry Mass (g)
1999
Grazed
Idled
High
Medium
Low
30
25
20
15
10
5
0
Dry Mass (g)
2000
High
Medium
Low
Transect Height

Figure 4.

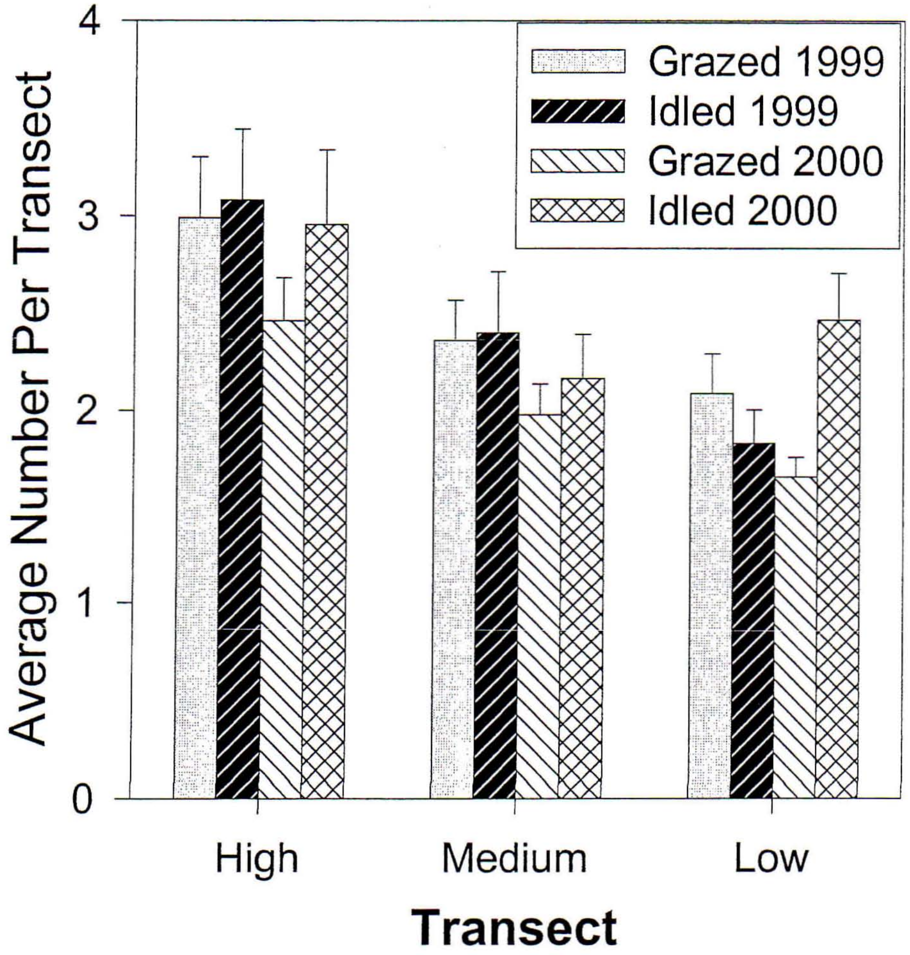
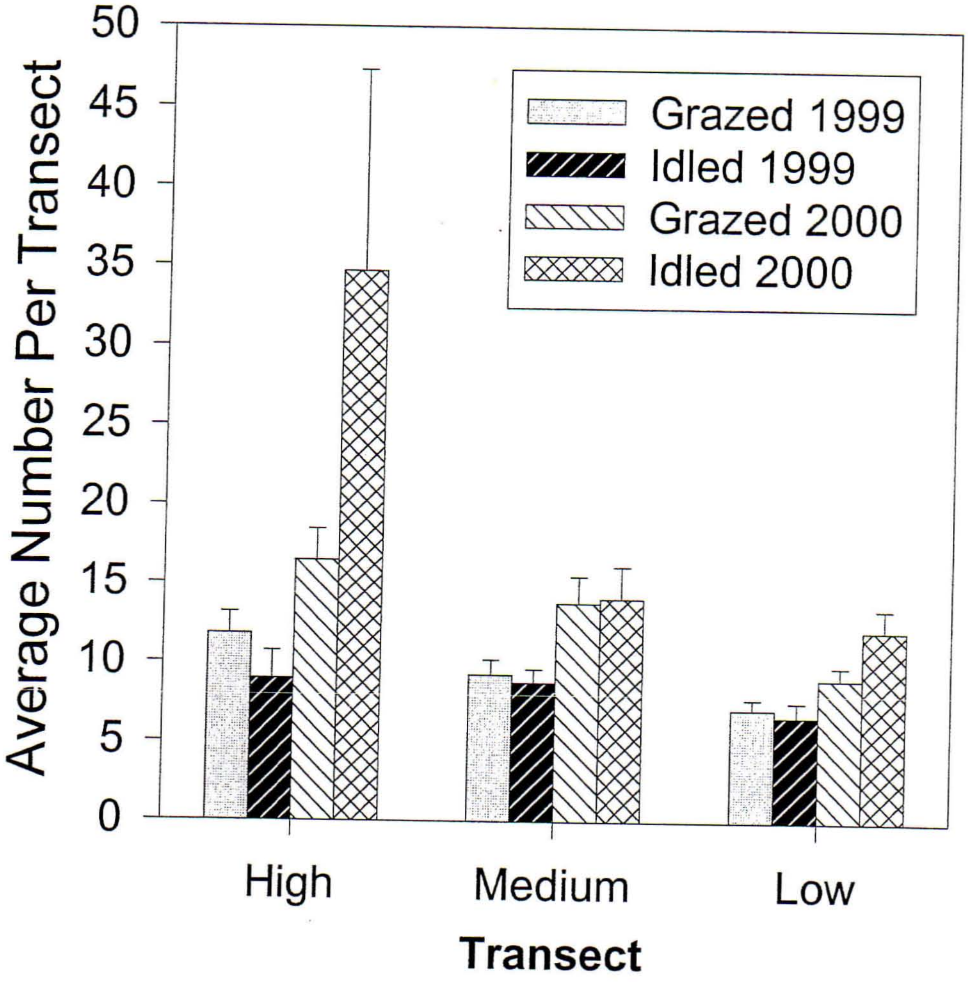

Average Number Per Transect
0
1
2
3
4
Grazed 1999
Idled 1999
Grazed 2000
Idled 2000
High
Medium
Low
Transect

Figure 5.


Average Number Per Transect
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5
10
15
20
25
30
35
40
45
50
Grazed 1999
Idled 1999
Grazed 2000
Idled 2000
High
Medium
Low
Transect

Figure 6.

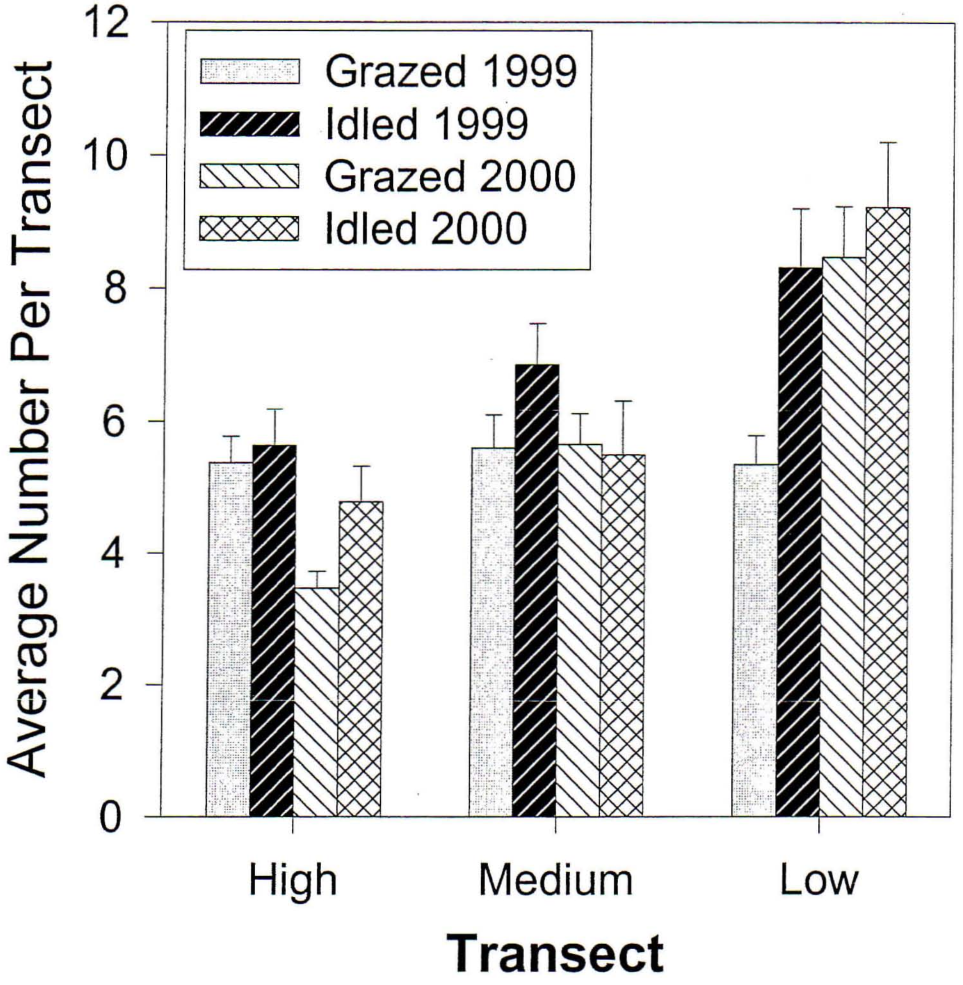
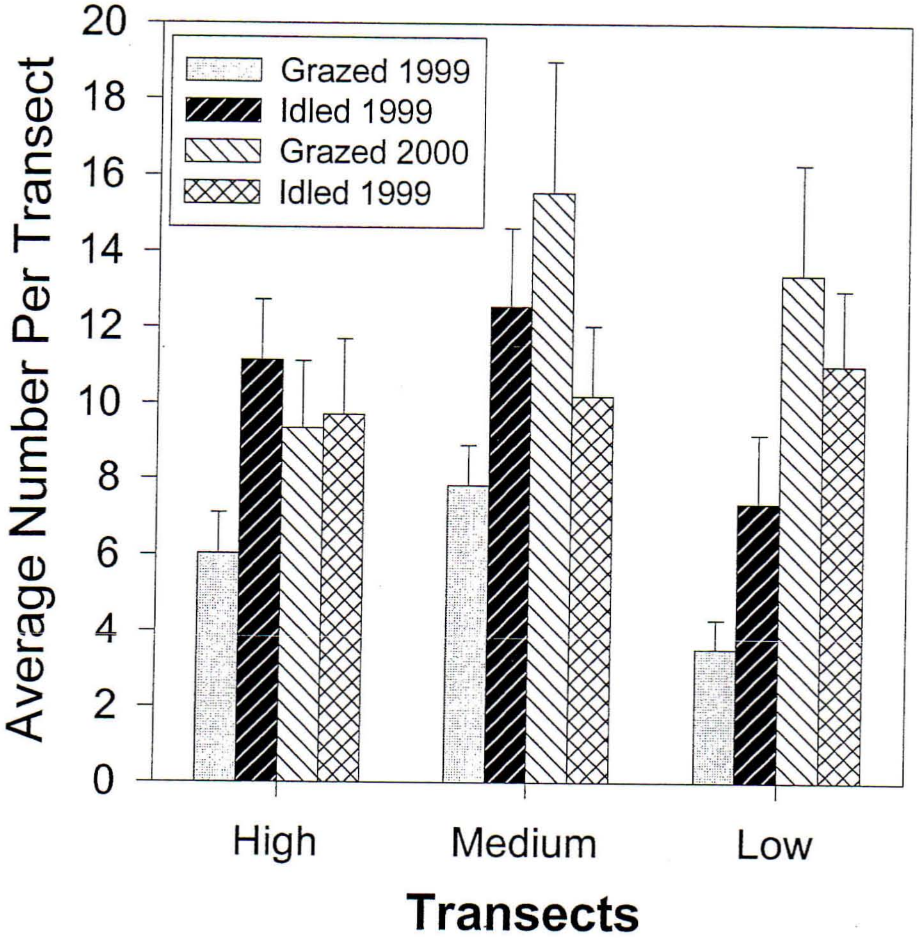

Average Number Per Transect
0
2
4
6
8
10
12
Grazed 1999
Idled 1999
Grazed 2000
Idled 2000
High
Medium
Low
Transect

Figure 7.


20
18
16
14
12
10
8
6
4
2
0
Average Number Per Transect
Grazed 1999
Idled 1999
Grazed 2000
Idled 1999
High
Medium
Low
Transects

Chapter 3:

Ground Beetle (Coleoptera: Carabidae) Assemblages in South-Central Nebraska in Wet Meadow/Cottonwood Forest Habitats

Justin R. Krahulik and W. Wyatt Hoback

Department of Biology, University of Nebraska at Kearney, Kearney NE 68849

Abstract

The Platte River in south-central Nebraska has been transformed by human intervention from a braided prairie river into a channelized river that is bordered by forest that has grown in the past 100 years. The impact of new forestation on the native fauna has been documented with migratory birds, such as sandhill cranes (*Grus canadensis*) and whooping cranes (*Grus americana*), but no attempt has been made to examine the impact that forestation has had on the invertebrate fauna. I collected ground beetles (Coleoptera: Carabidae) bi-weekly from wet meadows and cottonwood forest along the Platte River between May and October 2001. Ground beetles were sampled at 3 study sites with one transect at each study site beginning in native wet meadows and ending in the cottonwood forest. Specimens were identified to morphospecies in the laboratory. I collected 32 different morphospecies from the cottonwood forest and wet meadow habitats. Wet meadow assemblages were the most diverse with 18 species and ecotone habitats were the least diverse with only 11 species. Also wet meadow habitats had the highest number of unique species with 10 and ecotone habitats had the lowest number of unique species with only 6. Average daily temperatures from each habitat were not found to affect beetle assemblages but were found to have some influence on ground beetle activity. From my results, it appears that ground beetle fauna associated with wet meadow habitats along the Platte River in south-central Nebraska have begun to utilize the recently formed cottonwood forest habitat.

Introduction

Ground beetles (Coleoptera: Carabidae) are the dominant predatory insect group in the majority of terrestrial ecosystems (Lovei and Sunderland 1996). Their species diversity and predatory nature has led them to be used as indicator species to characterize different habitats by their presence and abundance (Assmann 1999, Drake 1998, Epstein and Kulman 1990, Grechanichenko and Guseva 1999, Haubold 1951, Koivula et al. 1999, Louw 1987, Luff et al. 1989, Maiolini et al. 1998, Niemela and Spence 1994, Thingstad 1987, Yamazaki 1999). Moreover, ground beetles have been used as biological indicators to compare pristine habitats with those which have been altered by human activity (Desender 1989, French et al. 1998, Heliola et al. 2000, Kotze and Samways 1999, Rushton et al. 1989), and to measure invertebrate response to habitat disturbances (Blake and Foster 1998, Davies and Margules 1998, Drtischilo and Erwin 1982, Duchesne et al. 1998, Honek 1988, Magura et al. 2000, Uetz et al. 1979). Although ground beetles have been characterized as a group in Europe, they are less-studied in North America and few studies have examined ground beetle response to succession.

A dominant feature of Nebraska is the Platte River which transverses the majority of the state. The Platte River system has been dramatically altered over the last 150 years primarily by the region's agricultural economy. The flow of the Platte River has been reduced and controlled by reservoirs that impound water for irrigation and produce hydroelectric power. The alteration of flows has markedly impacted the habitat structure surrounding the Platte River. Historically the Platte River was a wide braided prairie river with large shallow channels devoid of vegetation (Currier et al. 1985, Johnson 1994, Sidle and Faanes 1997). The historical river was bordered by wet meadows associated along the banks (Currier et al. 1985, Johnson 1994, Sidle and Faanes 1997). Because of human alteration, the Platte River has become a deeper narrower river system and wet meadows that were associated with the river have been converted for use in agricultural production or are being encroached upon by cottonwood (*Populas deltoidies*) forests (Currier et al. 1985, Johnson 1994, Sidle and Faanes 1997). The remaining wet meadows and the spreading cottonwood forest provide an excellent opportunity to study ground beetles, which are well represented in Nebraska with over 270 species recorded.

Ground beetle fauna have been documented to respond in various manners to the presence of forests. The majority of studies have characterized the response of the fauna to human removal of forest. In Hungary, Magura et al. (2000) found that deforestation drastically reduced ground beetle species and after the subsequent establishment of plantations, there were significant differences in the number of individuals, number of species, and in Shannon diversity compared to native forest. For rarer species, human induced changes in forest patchiness might threaten the continued existence of several ground beetles (Niemela and Spence 1994, Koivula et al. 1999). Niemela (1997) suggested that certain species of ground beetles depend on small habitat patches within a forest and alteration of these patches through deforestation will eliminate species that depend on those specific habitat patches. A comparison of ground beetles by Kotze and Samways (1999) found that the mean ground beetle abundance and species richness decreased gradually from forest to grassland. However, there has been no ground beetle studies of which we are aware to determine the effects of a recently established forest ecosystem encroaching into a grassland ecosystem.

Because the cottonwood forest is a relatively recent habitat (c.a. 150 years), it may provide new niches for wet meadow ground beetle species to exploit in the absence of competition from more dominant wet meadow taxa. The aim of this study was to determine the effect of forestation on the ground beetle fauna near the Platte River in south-central Nebraska. I conducted tests to determine if there were any differences between the assemblages occurring in the forest, wet meadow, and ecotone. I hypothesized that wet meadows would have a larger assemblage of ground beetle species compared to the forest because there would be no pre-adapted forest species able to utilize the newly established cottonwood forest.

Materials and Methods:

Study Sites

Ground beetles were sampled in wet meadow- cottonwood forest ecotones along the Platte River between Kearney, NE and Grand Island, NE. Three study sites were used for sampling ground beetles. Site 1 (Diple property) was located approximately 5.93 kilometers southeast of Gibbon, NE. Site 1 had approximately 65.35 hectares of wet meadow habitat and 225.4 hectares of cottonwood forest habitat. Site 2 (Rowe Sanctuary's Triplet Trail) was located approximately 7.48 kilometers southwest of Gibbon, NE. Site 2 had approximately 53.32 hectares of wet meadow habitat and 52.24 hectares of cottonwood forest habitat. Site 3 (PRT) was located approximately 11.43 kilometers southwest of Grand Island, NE. Site 3 had approximately 451.42 hectares of wet meadow habitat and 10.63 hectares of cottonwood forest habitat.

Sampling Procedure

Three transects were established at each site beginning in the wet meadow and ending in the forest. Transects were positioned at each site so there would be an equal amount of edge on each side of the transect. Ground beetles were sampled using pitfall traps consisting of five trap arrays in each transect. Each trap consisted of an 18.9 litter bucket that was covered with a plastic rain shield and had 0.3 meters of drift fencing made of plastic garden edging extending in three directions from the trap. An artificial substrate consisting of moist soil and paper towels was provided in the bottom of each bucket. No preservation solution was used to minimize non-target effects of pitfall trapping. Any organisms other than ground beetles were released from the trap.

Trapping occurred every other week beginning in May, 2001 and ending in October, 2001. Traps were opened on the beginning of each trapping week and ground beetles were collected every 48 hours during the week; traps were closed on the last trap day. Specimens were collected, transported to the laboratory for storage, and preserved by freezing until identification took place. All carabids were sorted to morphospecies for this study. I judged morphospecies based on distinct characteristics (color, size, abdomen shape, striations on elytra, etc.) that definitively set them apart from other specimens examined.

Environmental Data

Relative humidity and temperature were collected at each site using Hobo® data loggers. Loggers were placed at traps located 100 meters in the prairie, 100 meters in the forest, and at the ecotone, to determine if any environmental differences could account for differences between species assemblages in the wet meadow and cottonwood forest.

Statistical Analysis

Shannon-Wiener indices were calculated to determine species richness in each habitat type and Simpson indices were calculated to determine taxa evenness in each habitat. Chi-square Goodness of Fit tests (assuming equal occurrence across habitats) were performed to test for differences in number of species collected in each habitat type when 10 or more specimens of a species were collected. The relationship between temperature, relative humidity, and number of individuals collected was examined using linear regressions.

Results

The number of each ground beetle species collected from each habitat type and the total number of ground beetles collected from each habitat is shown in Table 1. Species A was the most numerous in all habitat types but was significantly more abundant in the prairie than in the ecotone or forest (Chi-Square Test; df = 2; $P < 0.005$). Species P was the second most abundant ground beetle collected and was found exclusively in the prairie. Species N had the third highest abundance and was also most abundant in the prairie and was collected significantly more often in the prairie than in the ecotone or forest (Chi-Square Test; df = 2; $P < 0.005$). Species E was the fourth most abundant species but there were no significant differences in its abundance between prairie, forest, and ecotone.

The average daily temperatures were similar among sites but the prairie had the highest daily average in the summer months, the forest had the highest daily average in the spring and fall months, and the ecotone was an intermediate in temperature between the two (Figure 1 a-c). Relative humidity was lowest in the prairie but seemed to be higher in the ecotone than in the forest (Figure 2 a-c). Occurrence of ground beetles was not related with humidity but increasing temperature showed some positive effects (Figures 3-5). The strongest relation between ground beetle abundance and temperature was found in the ecotone (r^2 value = 0.4041), followed by the prairie (r^2 value = 0.3272), and the weakest relationship was in the forest ($r^2 = 0.1779$). Prairie species were active at lower temperatures than species found in other habitats (Figures 3-5) and ecotone species were also active at lower temperatures than forest species (Figures 4-5).

The overall species abundance was greatest in the prairie followed by the forest and ecotone (Figure 6). The prairie had the highest number of unique species followed by the forest and ecotone (Figure 7). Surprisingly, the forest habitat had the highest Shannon and Simpson diversity while the prairie had the lowest Shannon diversity and was intermediate between the forest and ecotone for Simpson diversity (Figure 6).

Discussion

Contrary to other studies (Kotze and Samways 1999, Kotze and Samways 2001) the overall species richness (at the morphospecies level) of ground beetles was higher in the wet meadows than in the forest habitat (Figure 4). Of the morphospecies collected, 10 were exclusively found in the prairie, 8 were exclusive to the forest and 6 were found only in traps placed at the ecotone (Figure 5). Overall, 75% of the species collected were specific to forest, ecotone, or wet meadow habitats (24 out of 32 species). Of the species occurring in each habitat 56% were specific to wet meadow habitats, 47% cottonwood forest habitat, and 54% ecotone habitat. These results suggest that the central Nebraska ground beetle fauna is composed of both habitat generalists and specialists and that the fauna contains several edge species.

Several factors have been identified that can be used to explain the distribution of ground beetle species within a habitat. In their reviews of ground beetle literature, Thiele (1977) and Lovei and Sunderland (1996) found that two of the most important factors affecting ground beetle assemblages are temperature and relative humidity. The results of my study found no relation between ground beetle abundance and relative humidity in any of the habitats sampled and only weak relations between ground beetle abundance and temperature (Figures 3-5). However there was a trend from prairie to forest in ground beetle activity, with prairie assemblages being active at lower temperatures (approximately 5° C lower than edge assemblages and 11°C lower than forest species).

These differences may be explained in part by the limited amount of sampling that was conducted during this study. In addition the results may be explained because of a drought in 2000, which may have led to deaths of ground beetle larvae that are highly susceptible to desiccation (Lovei and Sunderland 1996). The latter case seems likely because there were fewer ground beetles caught in 2001 than during studies conducted in 1999 and 2000 (Krahulik unpublished data) at other wet meadow sites in south-central Nebraska.

Of the ground beetle species tested for habitat preference species A, P, and N showed a preference for prairie habitat over forest and ecotone habitats and species E showed no preference for any of the habitats. The prairie habitat had the highest totals in number collected and unique taxa, which may also indicate that ground beetles prefer wet meadow habitats along the Platte River in south-central Nebraska to the cottonwood forest habitats and the ecotone that is associated with the two. The results of the Shannon- Wiener and Simpson diversity indices correspond with current ecological thought that a disturbance in ecosystems leads to higher short-term diversity until an ecosystem equilibrates (Petraitis et al. 1989, Sousa 1984, Vandermeer 1996, Wootton 1998).

The significance of this study is that it provides the first examination of invertebrate response to the forestation of the banks of the Platte River. The alteration of flows and the resulting changes in habitat structure have impacted migratory birds, resident grassland birds, and based on my data, the dominant terrestrial insect predators. The changes have undoubtedly impacted many other species as well. Forestation has increased overall diversity of ground beetles through the presence of species that are found exclusively in the forest and ecotone. However, the cost of increasing diversity through the addition of exotic species (defined in its broadest sense as species which were not present in an ecosystem until habitat alteration by humans) is becoming more apparent (Pimentel et al. 2000) and must be carefully weighed in management decisions.

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Morpho Species	Habitat			Total Number
	Edge	Forest	Prairie	
A	37	29	113*	179
A2	1	0	0	1
B	0	0	1	1
B2	0	0	1	1
C	1	0	0	1
C2	0	0	1	1
D	0	2	1	3
D2	0	0	1	1
E	7	2	3	12
F	1	0	0	1
F2	0	9	0	9
G	0	0	2	2
G2	0	3	0	3
H	0	5	1	6
I	1	0	0	1
J	2	1	0	3
K	0	1	0	1
L	0	1	0	1
M	0	1	0	1
N	2	2	11*	15
O	0	1	0	1
P	0	0	16*	16
Q	0	1	0	1
R	0	0	1	1
S	1	0	0	1
T	0	0	1	1
U	1	1	1	3
V	0	0	1	1
W	0	2	1	3
X	1	0	0	1
Y	0	1	0	1
Z	0	0	3	3
Total	55	62	159	276

Table 1. Number of Each Morphospecies Located in Wet Meadow, Cottonwood Forest, and Ecotone and the Total Number of Each Species Collected. (* indicates significant difference)

Figure Legend

Figure 1a. Average Daily Temperature in Prairie Sites.

Figure 1b. Average Daily Temperature in Ecotone Sites.

Figure 1c. Average Daily Temperature in Forest Sites.

Figure 2a. Daily Percent Relative Humidity in Prairie.

Figure 2b. Daily Percent Humidity in Ecotone.

Figure 2c. Daily Percent Relative Humidity in Forest.

Figure 3. Average Temperature in Prairie Sites versus Number Collected.

Figure 4. Average Temperature in Edge Sites versus Number Collected

Figure 5. Average Temperature of Forest Sites versus Number Collected.

Figure 6. Number of Species Found in Each Habitat

Figure 7. Number of Taxa Found Exclusively in Each Habitat.

Figure 8. Shannon- Wiener and Simpson's Diversity Indices for ground beetle diversity and evenness in wet meadow, forest, and ecotone habitats.

Figure 1a.

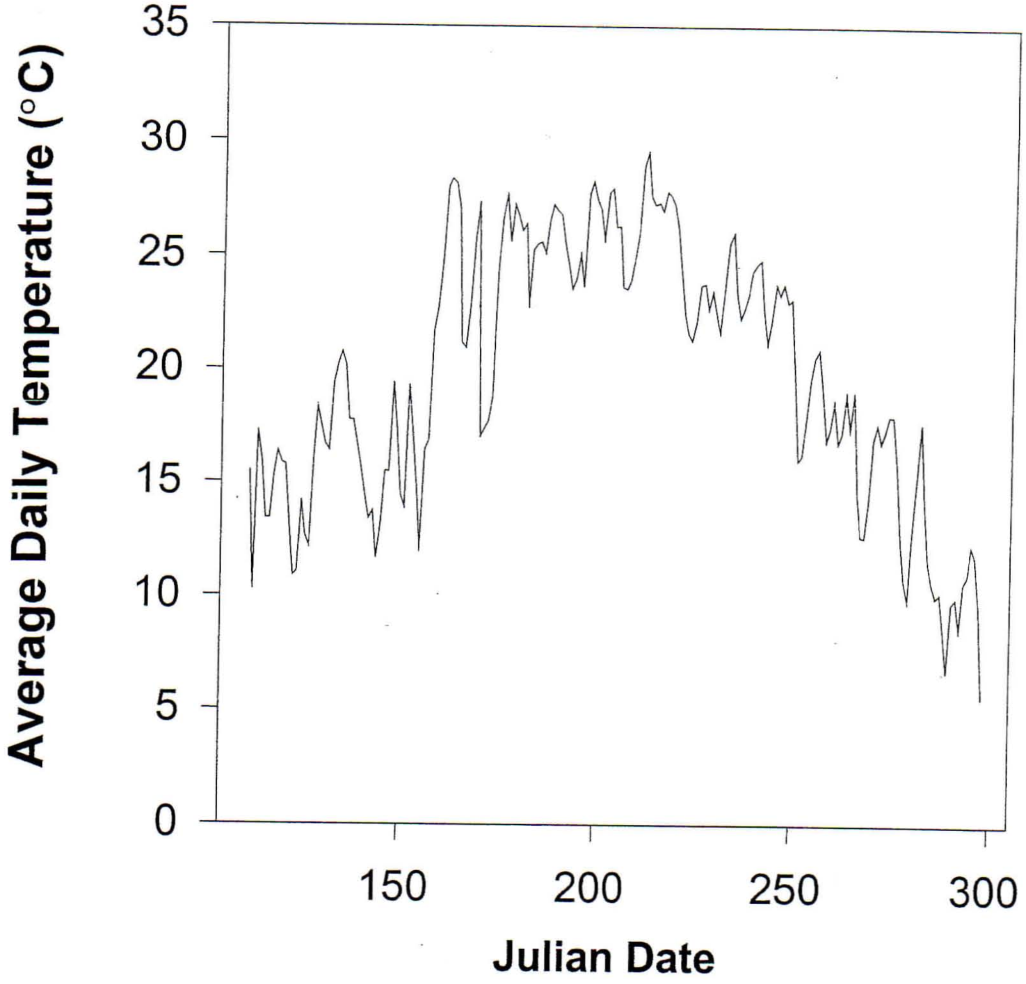

Average Daily Temperature (°C)
35
30
25
20
15
10
5
0
150
200
250
300
Julian Date

Figure 1b.

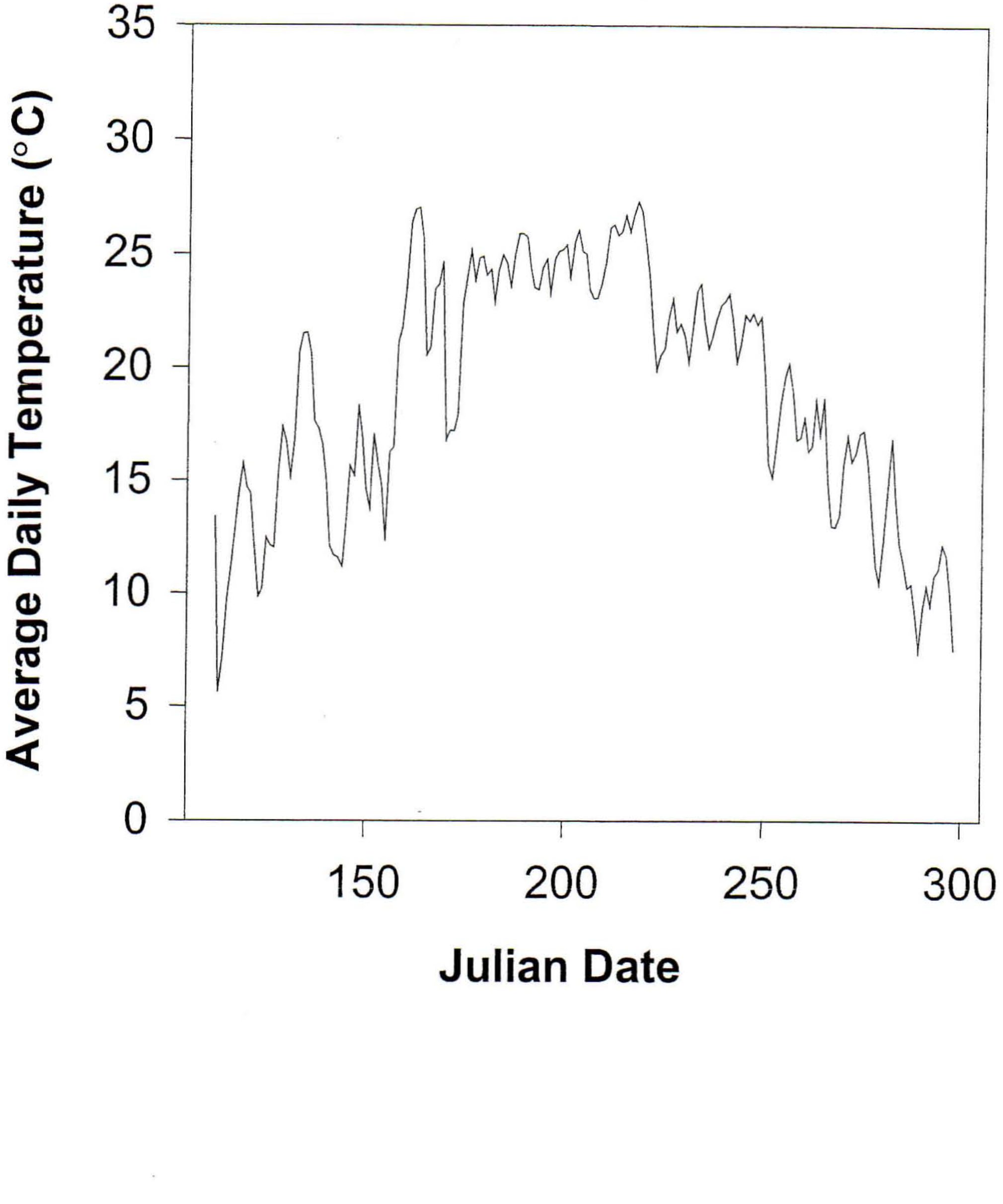

35
30
25
20
15
10
5
0
Average Daily Temperature (°C)
150
200
250
300
Julian Date

Figure 1c.

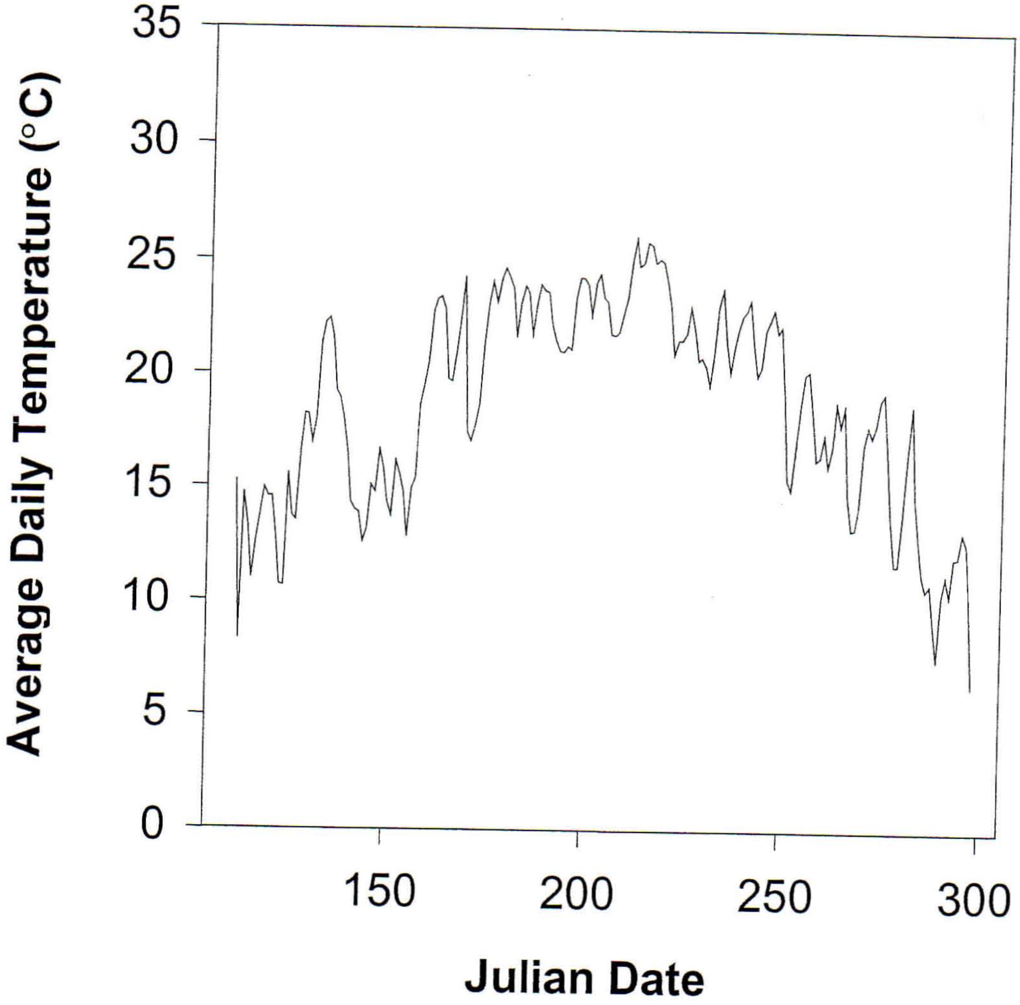

35
30
25
20
15
10
5
0
Average Daily Temperature (°C)
150
200
250
300
Julian Date

Figure 2a.

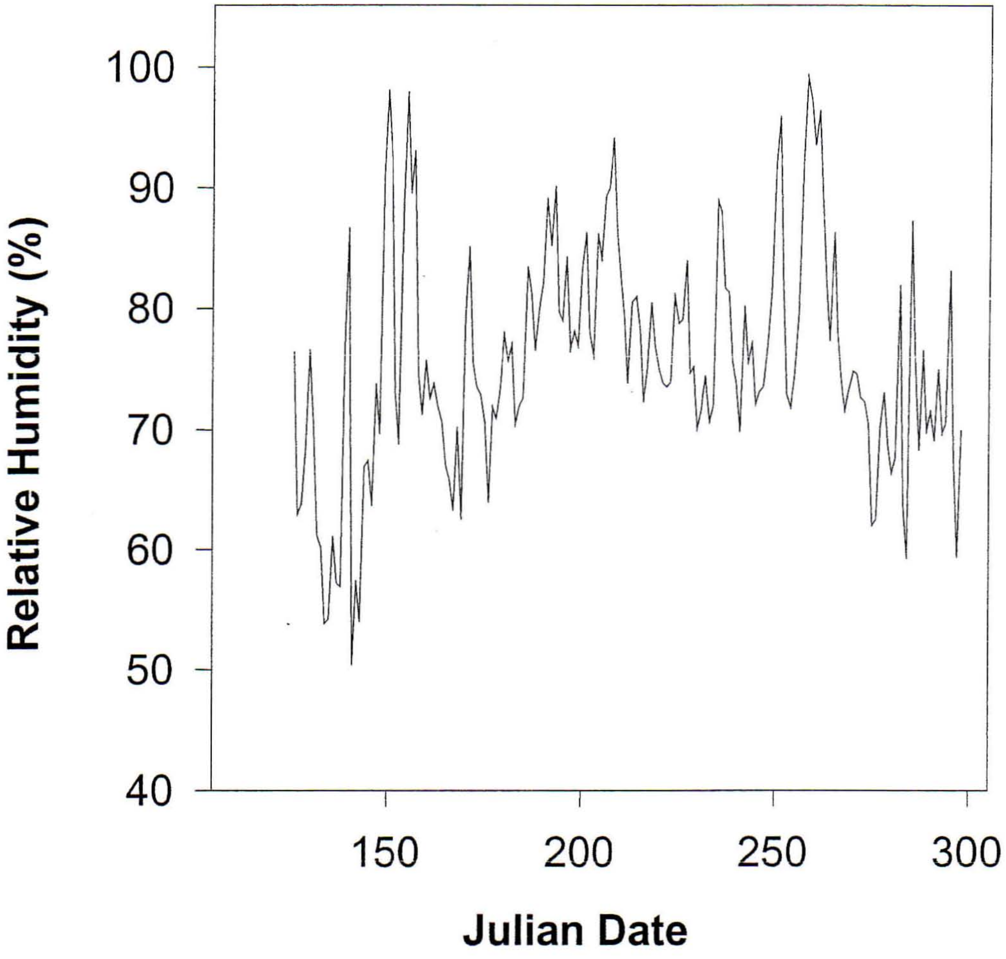

100
90
80
70
60
50
40
150
200
250
300
Relative Humidity (%)
Julian Date

Figure 2b.

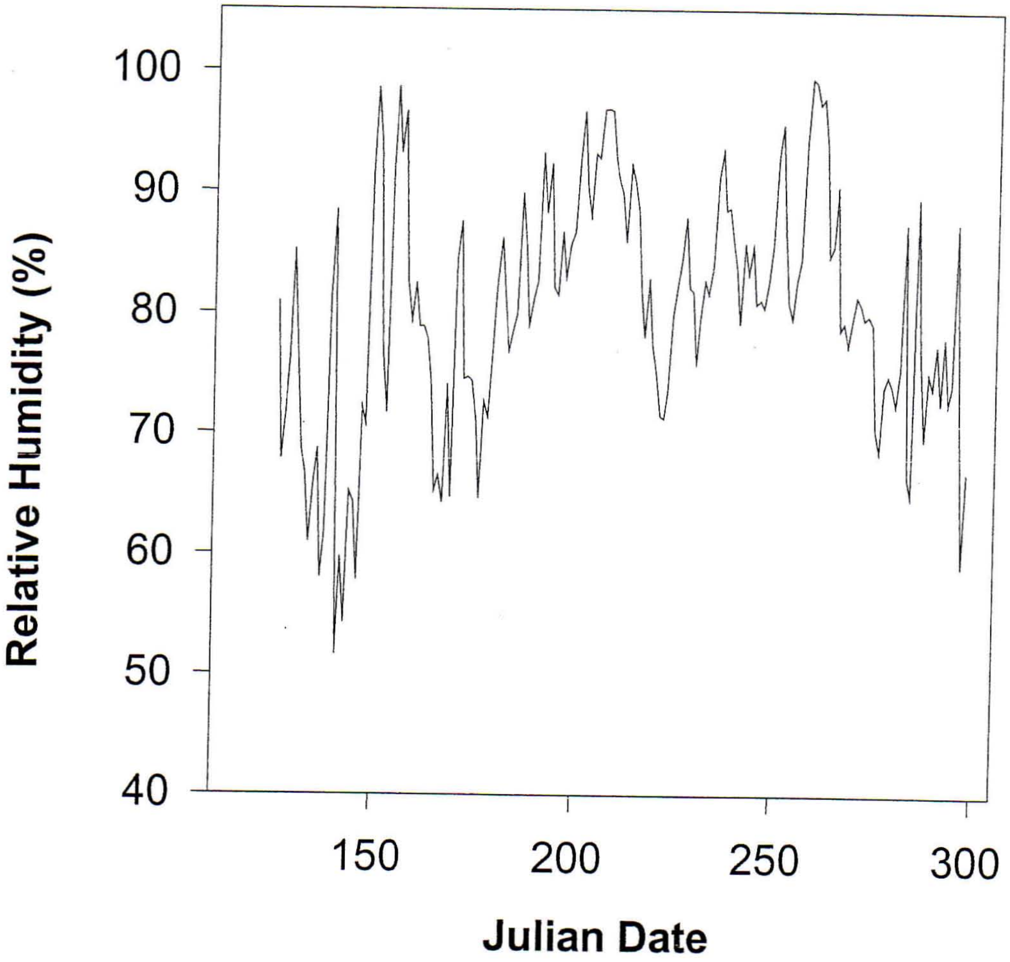

Relative Humidity (%)
100
90
80
70
60
50
40
150
200
250
300
Julian Date

Figure 2c.

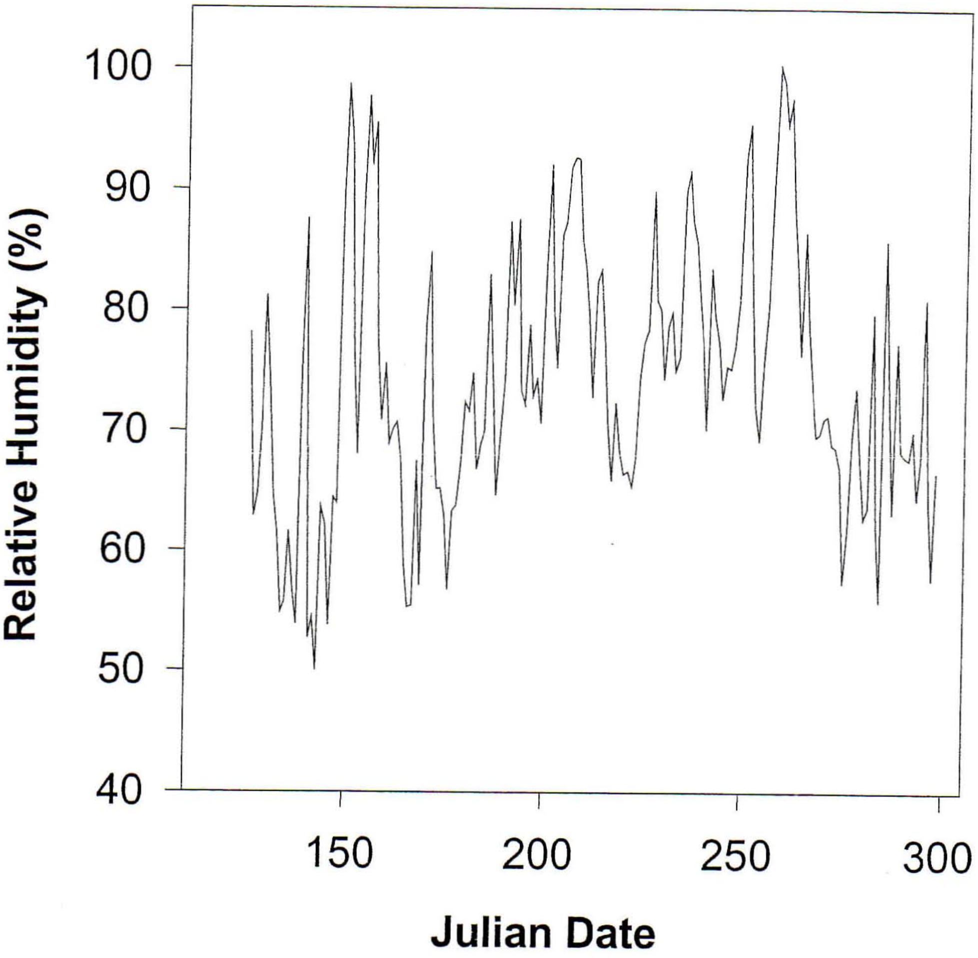

100
90
80
70
60
50
40
Relative Humidity (%)
150
200
250
300
Julian Date

Figure 3.

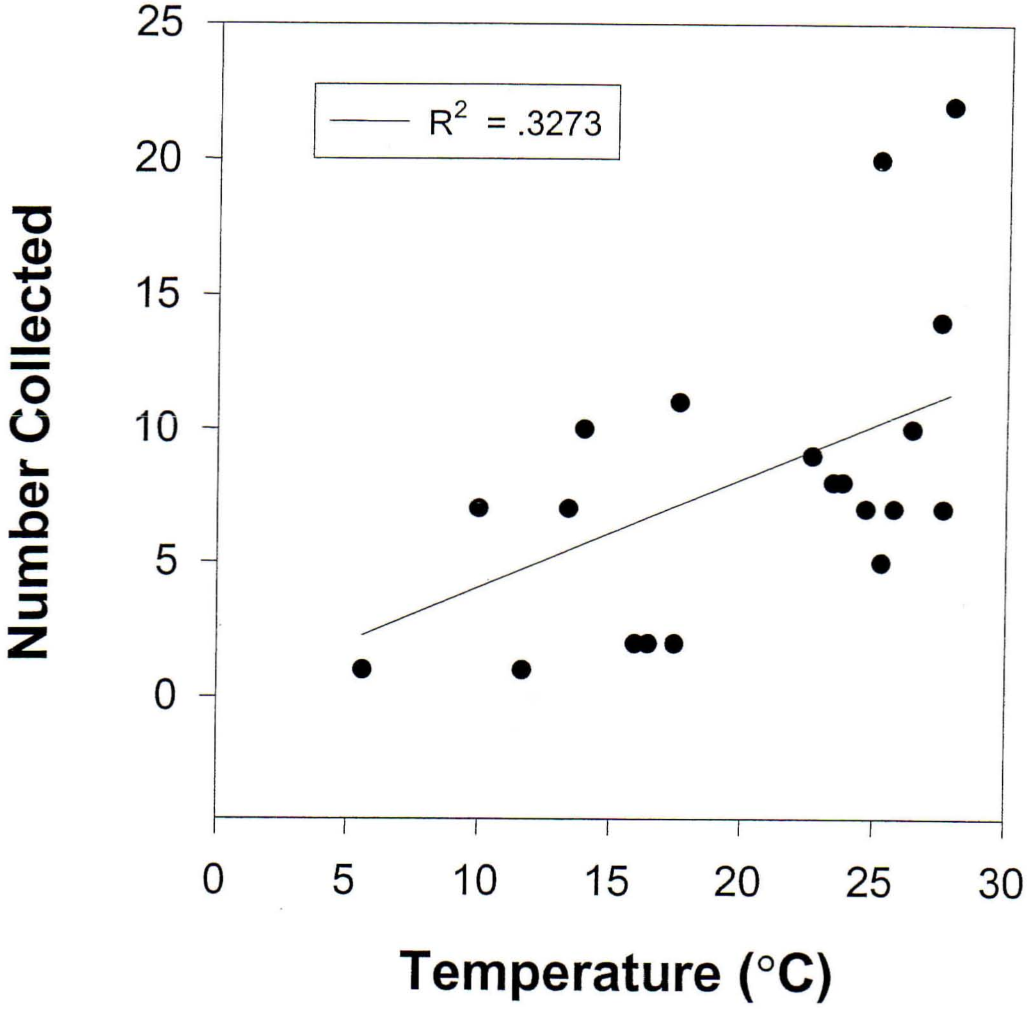

R^2 = .3273
Number Collected
0
5
10
15
20
25
0
5
10
15
20
25
30
Temperature (°C)

Figure 4.

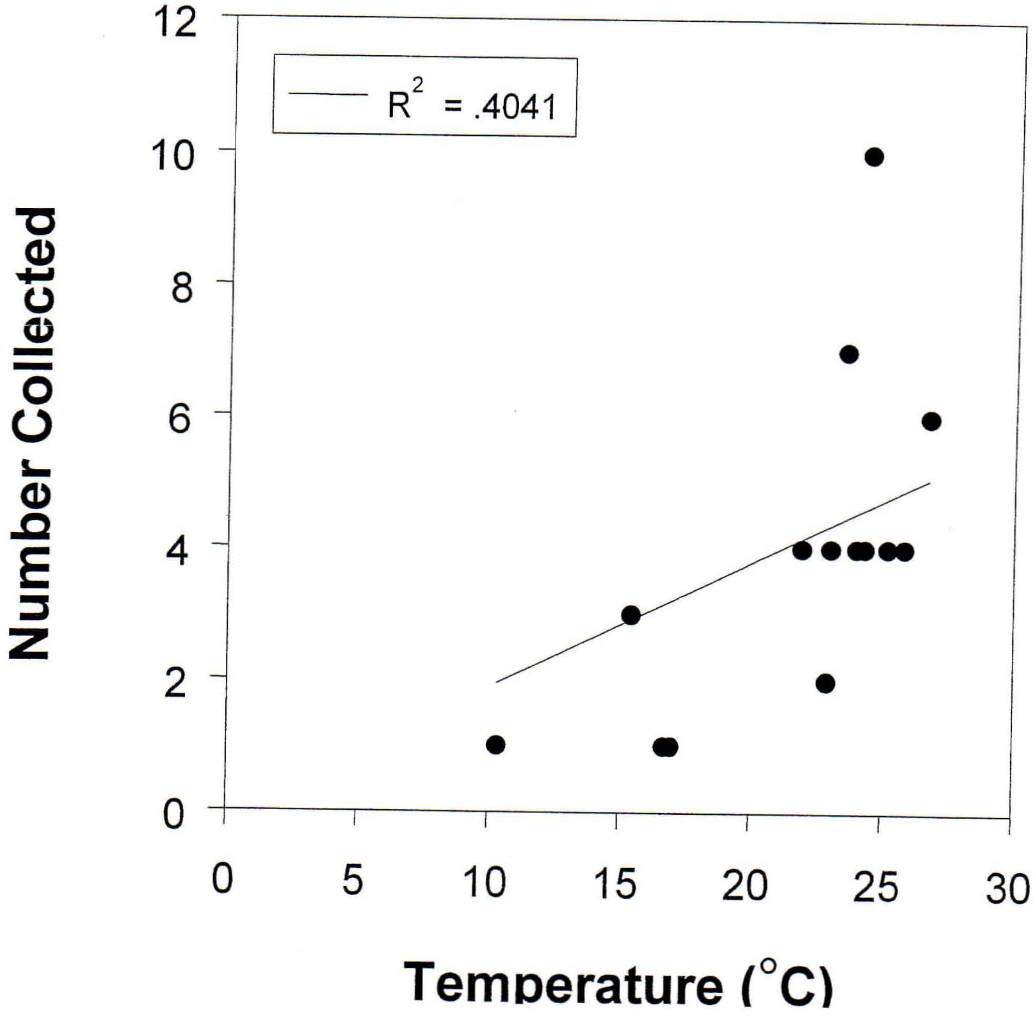

R² = .4041
Number Collected
0
2
4
6
8
10
12
0
5
10
15
20
25
30
Temperature (°C)

Figure 5.

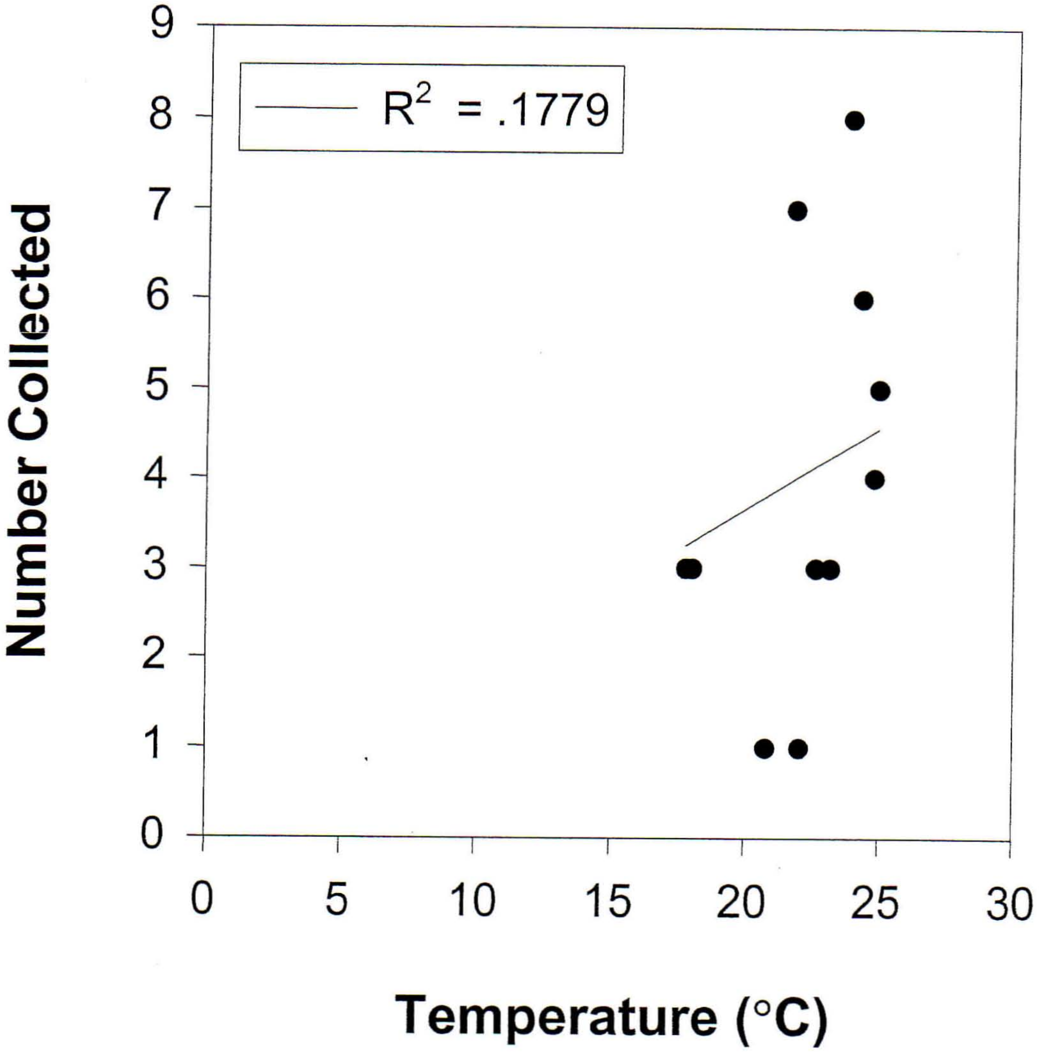

R^2 = .1779
Number Collected
Temperature (°C)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25
30

Figure 6.

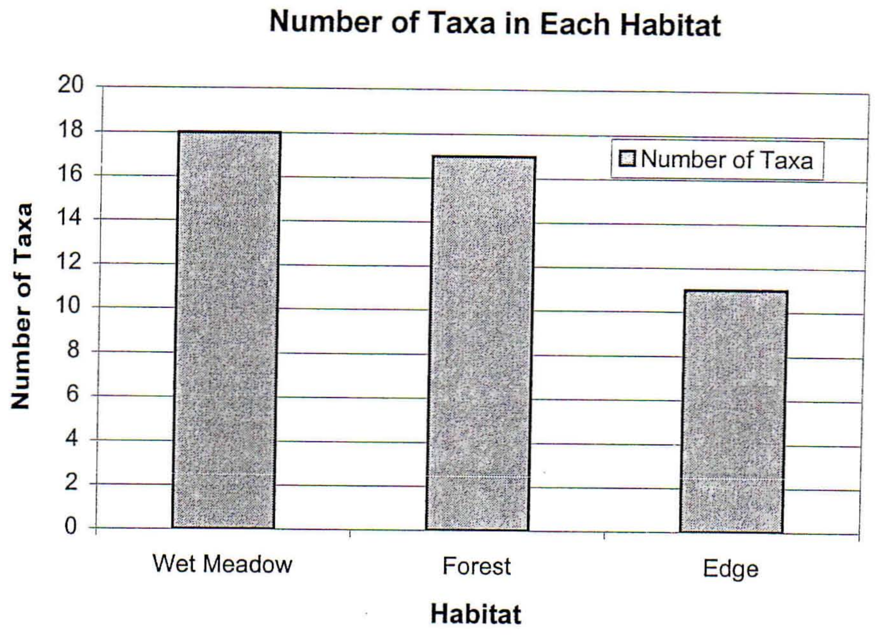

Number of Taxa in Each Habitat
20
18
16
14
12
10
8
6
4
2
0
Number of Taxa
▨ Number of Taxa
Wet Meadow
Forest
Edge
Habitat

Figure 7.

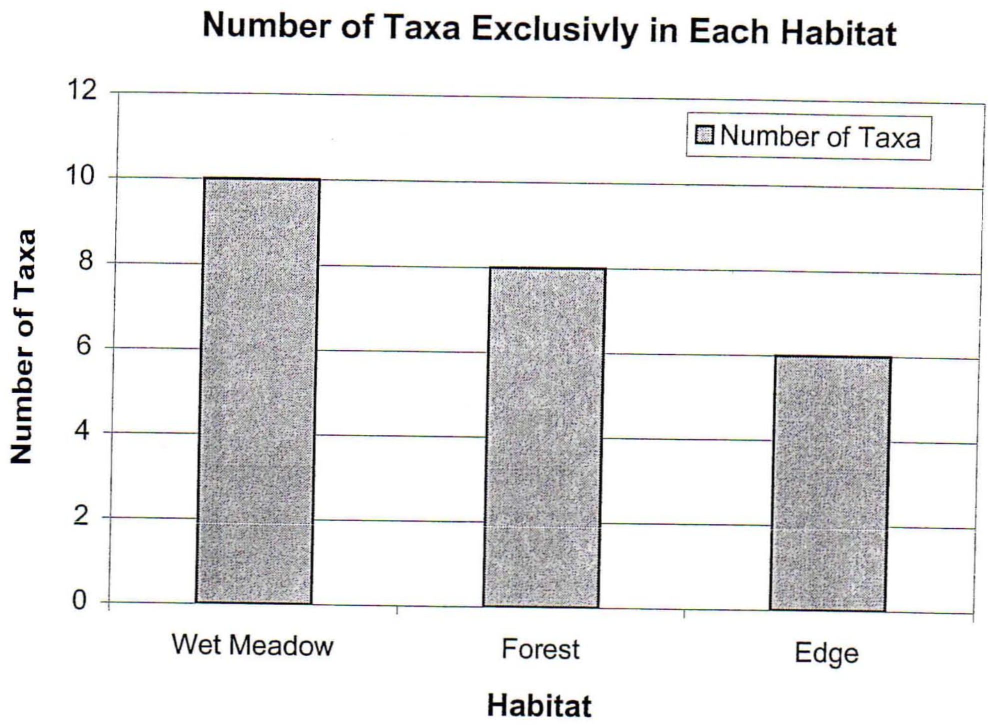
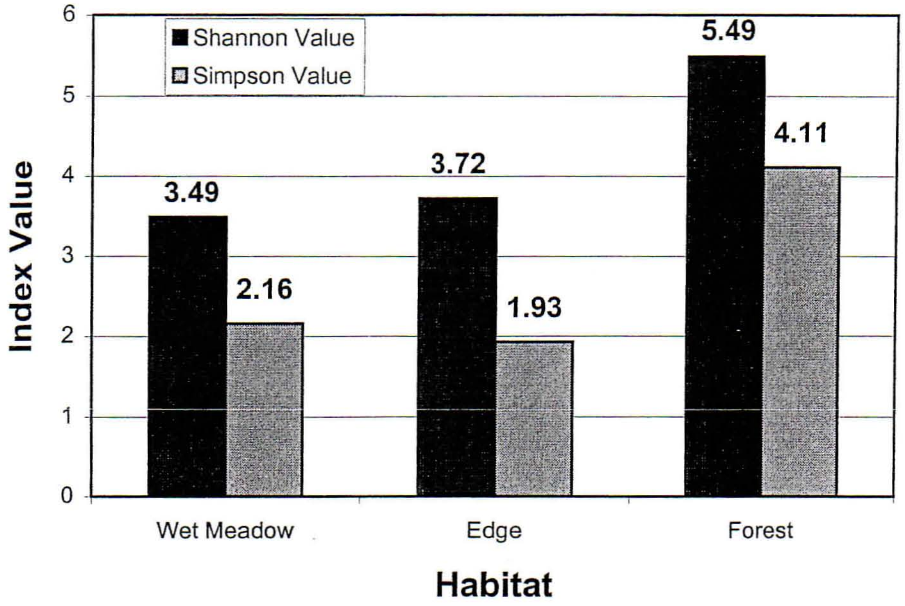

Number of Taxa Exclusivly in Each Habitat
12
10
8
6
4
2
0
Number of Taxa
▨ Number of Taxa
Wet Meadow
Forest
Edge
Habitat

Figure 8.

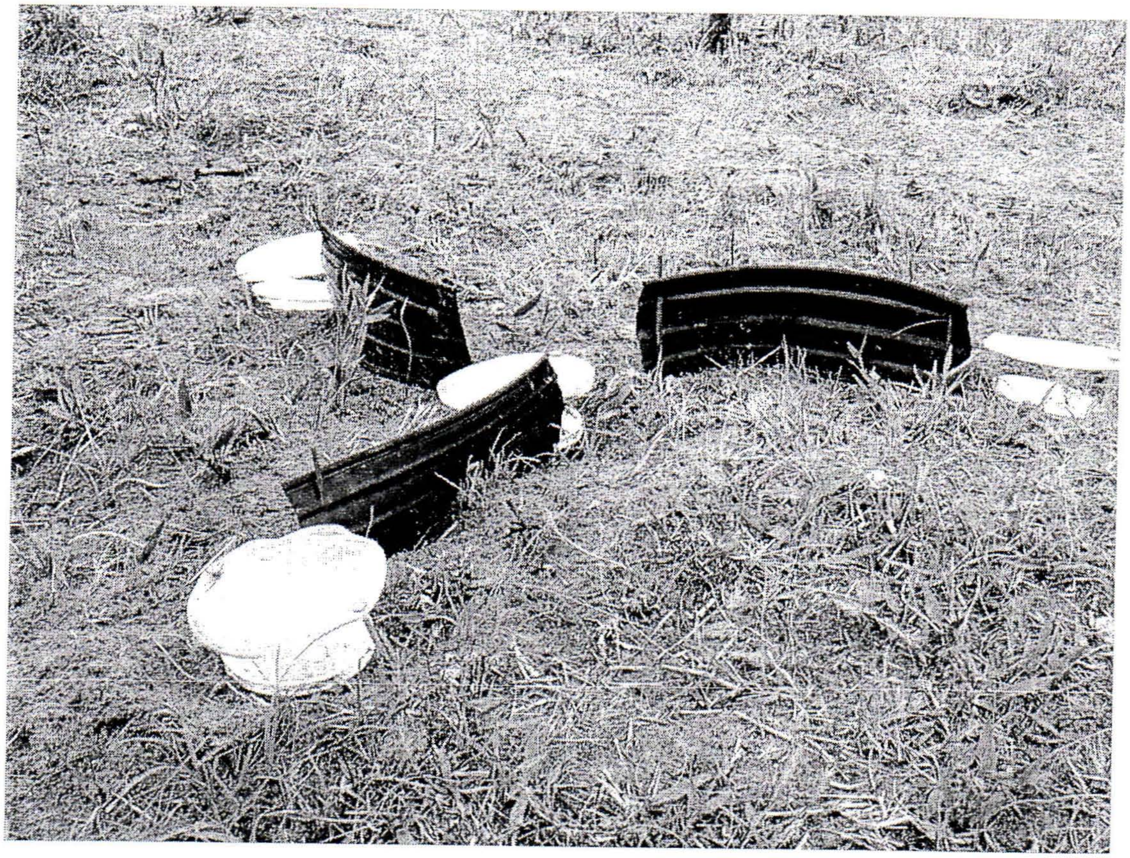

■ Shannon Value
▨ Simpson Value
Index Value
0
1
2
3
4
5
6
3.49
2.16
3.72
1.93
5.49
4.11
Wet Meadow
Edge
Forest
Habitat

Appendix

Figure 1. Example of wet meadow habitat at Mormon Island near Grand Island, Nebraska.

Figure 2. High transect in grazed management at Mormon Island (field 2) near Grand Island, Nebraska showing effects of grazing and lay out of pitfall arrays.

Figure 3. Low transect in grazed management at Mormon Island (field 2) near Grand Island, Nebraska.



Picture 4. Close-up of trap array used for testing the influence of grazing on wet meadow invertebrate communities in south-central Nebraska.

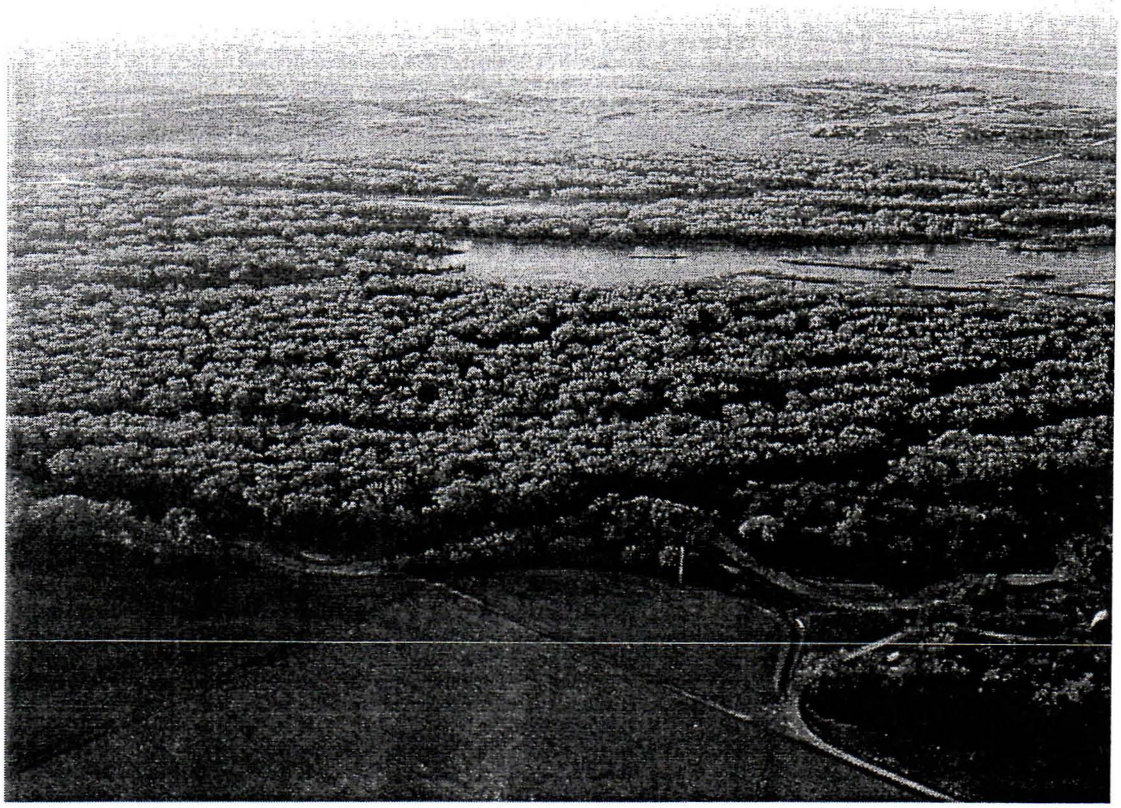


Figure 5. Example of cottonwood forestation along the Platte River near Chapmen, Nebraska.

Figure 6. Trap array used for ground beetle assemblages in south-central Nebraska in wet meadow/cottonwood forest habitats. Trap consists of a 5-gallon bucket.

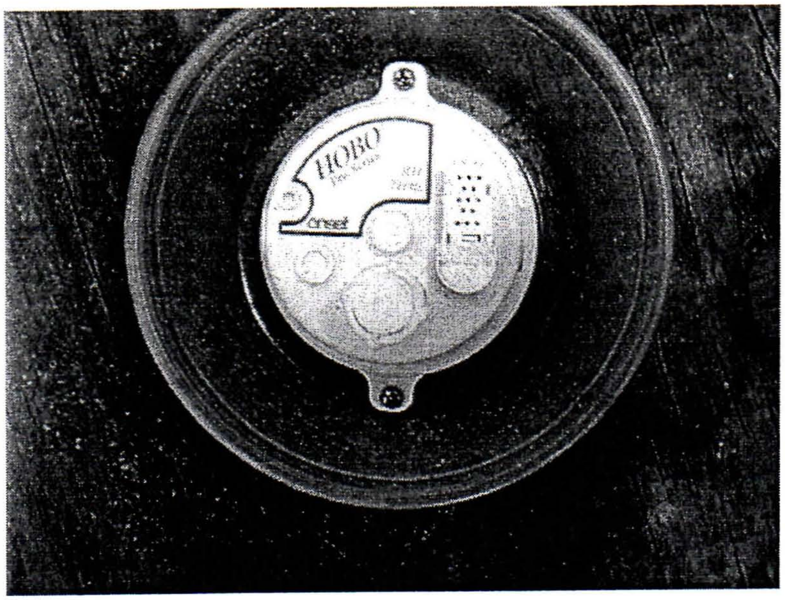


Figure 7. Picture of a HOBO® data logger used to record temperature and humidity.